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TENNESSEE VALLEY AUTHORITY

WATER CONTROL PLANNING DEPARTMENT

REPORT NO. 0-3075

FLOOD CONTROL

FOR

UPPER FRENCH BROAD RIVER

AND

TRIBUTARIES

A PRELIMINARY REPORT

KNOXVILLE, TENNESSEE

AUGUST 1942

TENNESSEE VALLEY AUTHORITY

KNOXVILLE, TENNESSEE

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September 12, 1942

Mr. Gordon R. Clapp
General Manager
Tennessee Valley Authority
Knoxville, Tennessee

Dear Mr. Clapp:

I am transmitting herewith a preliminary report on the French Broad flood control project, covering the flood situation on the upper watershed of the French Broad River as well as at Asheville. The text of this report was written by Mr. A. S. Fry of the Water Control Planning Department and is the result of investigations and studies made by that department at the request of citizens of Asheville and environs in September 1940.

This report analyzes the flood problems of the various areas and communities in the region, and discusses means for the alleviation of these problems. Although the greatest single point of flood damage is at Asheville, it appeared proper to consider also the protection of the fertile agricultural lands upstream. This latter could be accomplished by proper distribution of the reservoirs for the protection of Asheville. Accordingly, two plans are presented:

1. The Regional Plan, which provides for protection of the agricultural valley lands as well as for the protection of Asheville. The cost of this plan is estimated at \$8,210,000. The estimated tangible benefits are \$9,000,000, in addition to which there are other intangible benefits that are difficult to evaluate. This plan appears to be well justified by the consideration that the regional pattern in this area is such that the various communities are to a great extent interdependent.

2. The Asheville Plan, which provides only for the protection of the urban area contiguous to the city. The estimated cost of this plan is \$4,803,000, and the tangible benefits are estimated at \$5,400,000. This plan is not recommended, since its execution would practically preclude the protection of agricultural lands upstream that need relief.

Plans are also presented for protection for Marshall on the French Broad River, for Canton on the Pigeon River, and for Hominy Creek. The protective works suggested at these points are entirely local in character.

In making these studies, our engineers have cooperated very closely with the North Carolina State College and with many county agents in North Carolina as well as with our own Departments for Water Control on the Land. It is especially noteworthy that all of these agencies agree on the effect of improved land use on the situation and on the essential steps which must be taken to provide flood protection. The Authority's agriculture and forestry experts and engineers have cooperated in developing a means of solving an acute flood control problem.

It should be pointed out that this report is preliminary. No exploration of the foundations for the proposed structures has been possible and no layouts have been prepared in detail. However, the contingency allowances in the estimates of cost should permit reasonable deviation from the assumptions which have been necessary without affecting the feasibility or economies of the plans suggested.

No comment is made as to enabling legislation which may be necessary or as to methods of organization to permit the financing and execution of construction by whatever means seem most appropriate at the time. It is assumed that in any event a project of this nature would not be started until after the war emergency. The main purpose of the report is to indicate a solution for the serious flood problems of the region so as to prepare the way for actual construction when conditions permit.

Yours very truly,

T. B. Parker

T. B. Parker
Chief Engineer

FLOOD CONTROL FOR

UPPER FRENCH BROAD RIVER AND TRIBUTARIES

A PRELIMINARY REPORT

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ILLUSTRATIONS

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ILLUSTRATIONS

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FIGURE 1 — BILTMORE SECTION OF ASHEVILLE FLOODED BY SWANNANOA RIVER AUGUST 30, 1940

Flood of August 13 was 3 feet higher causing large losses to industries and commercial concerns.

Flood of July 1916 was 6 feet higher than that of August 30, 1940. *(Asheville Citizen-Times photo)*

FLOOD CONTROL FOR UPPER FRENCH BROAD RIVER AND TRIBUTARIES

A PRELIMINARY REPORT

I. SUMMARY

The Upper French Broad region, which includes the city of Asheville, is subject to large floods which cause heavy damages, deterioration of property values, and loss of life. The greatest flood in the past 150 years at Asheville occurred in July 1916 causing flood losses of about $4,000,000. Other large floods in recent years have occurred in August 1928 and August 1940.

At the request of a committee of citizens, industrialists, and agriculturists of western North Carolina, an investigation has been made by the Tennessee Valley Authority of the flood situation in the Upper French Broad watershed and plans have been developed to provide protection against floods. These plans are necessarily preliminary. The flood control problems of the Upper French Broad region are extremely complex and neither time nor data have been available to make complete surveys, investigations, and studies necessary for the development of a final plan. Such investigations must be carried out prior to undertaking construction of the proposed works.

Asheville and the watershed upstream may be considered as one flood problem. Separate flood situations exist at the town of Marshall on the French Broad River downstream from Asheville, on Hominy Creek, and on the Pigeon River, including the town of Canton. The plans for flood control for each of these locations are described briefly here and in more detail in succeeding sections of this report.

Regional Plan for Flood Control

Along the right bank of the French Broad River and on both sides of the Swannanoa through Asheville, the flood plains have been built up with industries and commercial establishments which suffer heavy damages from floods. Expansion in these areas is held back by the flood hazard. Upstream from

Asheville, in the valley of the main river and principal tributaries, are valuable agricultural lands, the development of which has been retarded because of flooding and loss of crops. Potentially much of this area is considered by agriculturists to be susceptible to intensive development for truck crops of high per acre value.

There are two classes of property which need protection, one urban and the other rural. For urban property it is desirable that protection be provided against the maximum possible floods. For agricultural lands, it is economically sound to provide protection against floods which happen at frequent intervals but not against extreme floods of rare occurrence.

Considering the Upper French Broad region above Asheville, including the city and the agricultural valley lands, a plan has been worked out to provide flood protection. This includes seven storage reservoirs of the detention basin type at the locations shown on plate 4 and a levee along the French Broad River at Asheville. The Azalea Reservoir on Swannanoa River which is essential for the protection of the industrial area along the river through the Biltmore section of Asheville is of sufficiently large capacity to control all floods on that river. The other reservoirs are designed to provide agricultural flood protection and about once in twelve years on the average some flooding of the valley lands may be expected. All of the reservoirs are detention basins which hold water only a few days after a flood and thus permit the use of the lands within the reservoirs for general farming purposes as in the past. The cost of this plan is estimated at $8,210,000. The estimated tangible benefits from flood protection under the plan are $9,000,000. In addition, there are intangible benefits which although real are difficult to evaluate.

Asheville Only Plan

An alternate plan has been developed for the protection of the industrial and commercial areas along the French Broad River and the Swannanoa River in Asheville, leaving out the protection of the agricultural valley lands upstream. This is shown on plate 5. The cost of this plan is estimated at $4,803,000. The estimated tangible benefits principally to the

city of Asheville are $5,400,000. This plan would not benefit any of the lands along the river and its tributaries upstream.

Marshall

The business portion of this town lies on a narrow flood plain on the right bank of the French Broad River. Large floods cause considerable losses to business concerns in the town and to the Southern Railway. Flood protection works above the city of Asheville will lower the height of some floods at Marshall, but the area between Asheville and Marshall, some 400 square miles, is capable of producing large floods which would overflow Marshall. Such a flood occurred in late August 1940. Because of the small area and character of property flooded, the benefits from flood protection are limited. The cost of protection is high. Three plans have been developed which include a concrete levee along the right edge of the river bank and which afford respectively, protection against maximum floods, protection against a flood of the height of that of July 1916, and protection against a flood of the height of that of 1940. The costs of these plans respectively are $767,000, $516,000, and $297,000.

Hominy Creek

The chief flood problem on this creek is that of the large industrial plant of the American Enka Corporation located in a flat area along the creek eight miles above the mouth. Great damages were suffered by this plant during the late August 1940 flood. Reservoir control of Hominy Creek is not feasible but protection against maximum floods can be obtained at a relatively low cost by raising the existing levee around the Enka plant. The cost of this is estimated at $114,000. This is a small fraction of the damages which would be suffered by any one large flood.

Pigeon River

Flood problems on this stream are chiefly those at Canton and upstream. Both 1940 floods damaged the agricultural lands in the river valley but did most damage to the large plant of the Champion Paper and Fibre

Company in Canton. Commercial establishments in Canton also suffered. Control of the Upper Pigeon River by reservoirs is not feasible. The flooded area in Canton can be most economically protected by levees and two plans are presented, one, for protection 5 feet above the late August 1940 flood, and the other, for protection 10 feet above that flood. Some benefits to the agricultural lands above Canton may be accomplished by channel improvements. The cost of the two levee plans are respectively $101,000 and $172,000. In both cases, the cost is less than the loss that would be suffered in Canton from any one large flood.

Power Development and Flood Control

Since floods from the area above Asheville may be expected at any season of the year, storage in reservoirs must be reserved at all times for flood water. Reservoirs must be emptied immediately after each flood so that the water could not be used for generating power. It does not appear feasible because of existing developments to increase the height of the dams and provide higher levels for storage. The establishment of permanent reservoir levels for power would entail much additional expense for reservoirs and would flood large areas of bottom lands, thereby defeating the purpose of the Regional Plan for flood control which is designed to protect these lands from inundation.

Influence of Land Cover on Flood Control

The Authority and North Carolina State College of Agriculture and Engineering have made cooperative studies of the effect of a program for improved land use and management for both agricultural and forest lands on flood heights and total water conservation throughout the Upper French Broad region. Results show that improved land use and management will lower flood heights, the greatest effects being on small or moderate sized floods. Recognition of these benefits has been taken in the preparation of the engineering plans by lowering the Asheville levee one foot.

Small Watersheds

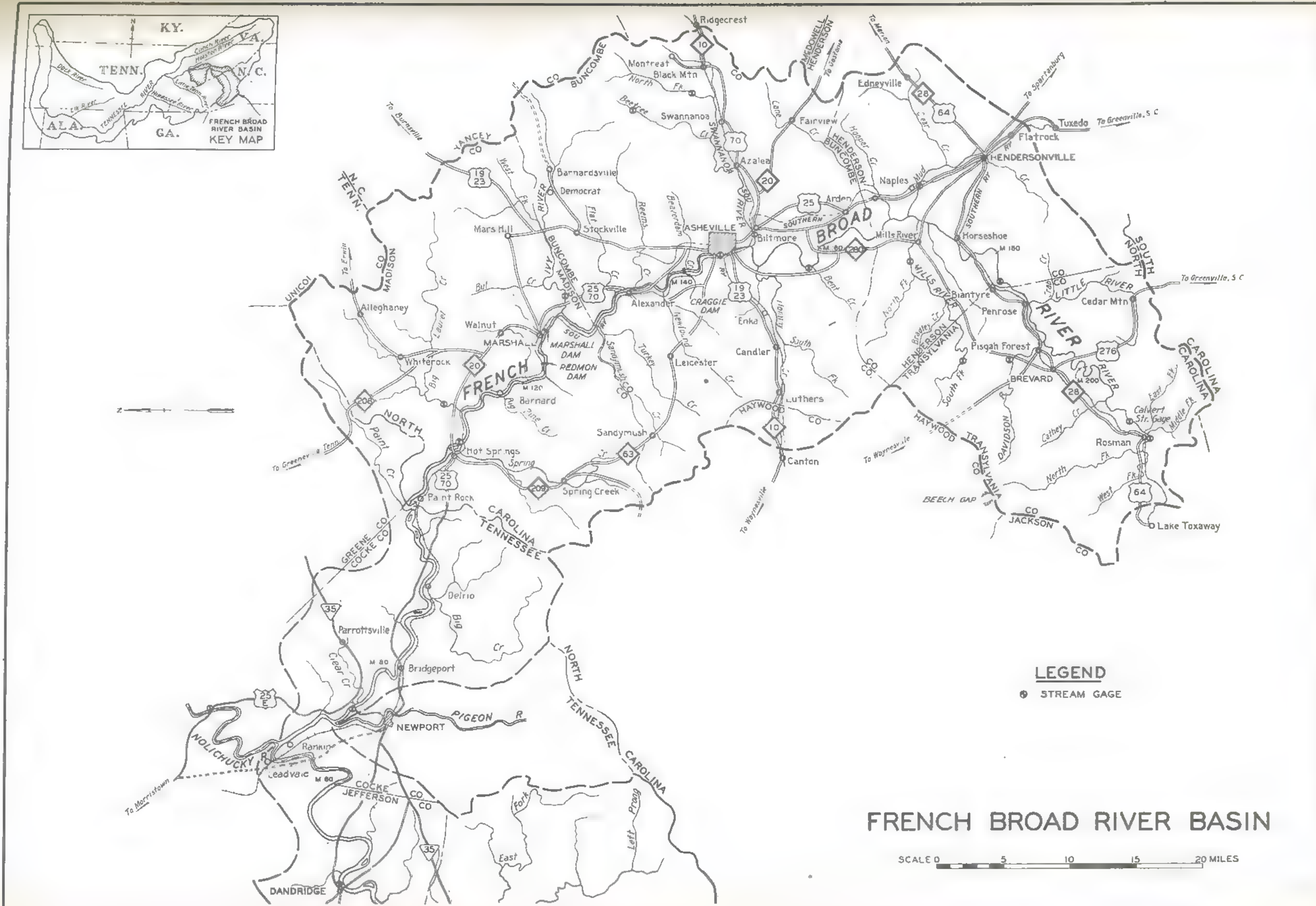
Consideration has been given to the problems of small watersheds in the region. These are subject to very intense localized rainfall which results in floods which destroy land and property and often cause loss of life. Protection against these catastrophic occurrences does not appear to be possible. Prompt aid in rehabilitation after a flood is the best means of holding the permanent damage to a minimum.

Cooperative Features of Planning

In the preparation of this report there has been cooperation between the Authority's engineers, agriculturists, and foresters and state agencies, Federal agencies, local communities, and private organizations. Among these are the North Carolina State College Extension Service and Experiment Station, county agents of western North Carolina counties, cities of Asheville, Canton, Marshall, and many industrial and commercial concerns. Other Government agencies, including the U. S. Geological Survey, the U. S. Weather Bureau, and the Appalachian Forest Experiment Station, have made valuable contributions to the investigations.

Make-up of Report

This report is divided into ten sections, including this one. The next succeeding section describes generally the region and its flood problems, and presents plans for flood protection with summarized costs and benefits. This is followed by sections devoted respectively to Asheville, to Marshall, to the valley above Asheville, and to each major tributary stream. These describe the problems peculiar to each location and the proposed flood protection works for that locality. Other sections discuss the influence of land use and cover on flood control and total water conservation and the problems of small watersheds. Supporting details for various parts of the report are contained in seven appendices.


FRENCH BROAD RIVER BASIN
LEGEND
STREAM GAGE
SCALE 0 5 10 15 20 MILES
FRENCH BROAD RIVER BASIN KEY MAP
KY.
VA.
TENN.
N.C.
ALA.
GA.
ASHEVILLE
HENDERSONVILLE
BREVARD
NEWPORT
DANDRIDGE
Biltmore
Ridgecrest
Montreat
Black Mtn
Swannanoa
Azalea
Fairview
Edneyville
Tuxedo
Flatrock
Naples
Arden
Mills River
Horseshoe
Blantyre
Penrose
Pisgah Forest
Cedar Mtn
Rosman
Calvert
Lake Toxaway
Canton
Luthers
Candler
Enka
Leicester
Alexander
Sandymush
Spring Creek
Hot Springs
Paint Rock
Barnard
Marshall
Walnut
Whiterock
Alleghaney
Mars Hill
Stockville
Democrat
Barnardsville
Delrio
Parrottsville
Bridgeport
Rankin
Leadvale
CRAGGIE DAM
MARSHALL DAM
REDMON DAM
FRENCH
BROAD
RIVER
PIGEON R
NOLICHUCKY R
To Greenville, S.C.
To Spartanburg
To Marion
To Waynesville
To Burnsville
To Erwin
To Morristown
BEECH GAP

II. GENERAL PLAN FOR FLOOD CONTROL

Floods of 1940 and Earlier Years

In August 1940, two floods occurred in western North Carolina which caused great damages throughout the entire region of which the Upper French Broad watershed is a part. The cities of Asheville, Canton, and Marshall suffered heavy damages. Large industries were flooded and machinery and stocks damaged. Railroads and highways suffered washouts of road beds and bridges and travel was disrupted. Business establishments and residences were flooded with damages to structures, stocks, and furnishings. Buildings were carried away. Telephone and telegraph communications were broken. Agricultural crops in the stream valleys were ruined by overflow. Several lives were lost in the French Broad region in addition to those lost in other parts of the storm area. The damages from both floods in the Upper French Broad watershed are estimated to have been $2,600,000.

These disastrous floods followed previous large floods in recent years which occurred in August 1928 and July 1916. The flood of July 1916 is remembered as the greatest flood that has occurred in western North Carolina since the settlement and development of this region. During that flood, damages to property within the French Broad watershed amounted to over $4,000,000. About half of this occurred in Asheville on the French Broad water front and along the Swannanoa River through Biltmore where there is extensive industrial development. The occurrence of a flood of this magnitude at the present time would result in damages of nearly $5,000,000.

Citizens Flood Control Committee

As a direct result of the damages suffered by the 1940 floods following those of 1928 and 1916, a movement was launched in western North Carolina, centered at Asheville, which resulted in the formation of a Citizens Flood Control Committee. This Committee has for its objective the determination of how the Upper French Broad region can be protected against future floods. In furtherance of this objective, this Committee, together

with representatives of agricultural and industrial interests in western North Carolina, held a conference in Knoxville, Tennessee, February 21, 1941, with representatives of the Tennessee Valley Authority. The Authority was requested to make surveys and investigations to determine practical methods of flood control for the Upper French Broad River and the feasibility of flood control works for the protection of this region. The Authority agreed to make this study.

Scope of Investigations

This investigation was to include "a study of the magnitude and frequency of past floods, an estimate of the magnitude of floods which may reasonably be expected in the future, an estimate of past flood damage and the extent of the existing flood hazard, a suggested plan and an estimate of cost for the prevention of floods or the alleviation of flood damage and the benefit which may be anticipated from such a plan." The investigation was to cover the flood problems of the basin above the mouth of the Nolichucky River. This includes the urban centers of Asheville, Brevard, Hendersonville, Marshall, and Canton. Consideration was to be given to the protection and improvement of the watershed through better land use as an aid to alleviation of flood damages. Flood problems of small watersheds and small communities were to be studied. The cooperation of state and local agencies was to be taken advantage of wherever appropriate in the conduct of the investigations.

French Broad Region

Topography

The Upper French Broad watershed above the mouth of the Nolichucky River includes an area of 2598 square miles located mostly in western North Carolina and partially in east Tennessee. At Asheville, the drainage area is 945 square miles. Plate 1 is a general map of the watershed. The area lies in the Southern Appalachian Mountain region and is of generally rugged topography. The lands vary in elevation from about 2000 feet along the main

river valley to above 6000 feet in the high mountains along the watershed divide. From Asheville to the head of the French Broad, the highest mountains are on the western boundary of the basin instead of on the divide which separates the French Broad drainage from that flowing to the Atlantic Ocean. This topographic situation has a marked influence on the rainfall over this area and consequently on the character and size of floods.

River System

The main river heads in the mountains southwest of Asheville where four headwater forks come together. Following a somewhat winding course of 215 miles around a half circle through the Upper French Broad Valley, past Asheville, Marshall, and Newport the river joins with the Holston River just above Knoxville to form the main Tennessee River. From the head of the river to Asheville is 70 miles and from Asheville to Marshall is 22 miles. The principal tributaries upstream from Asheville are the Swannanoa River, Cane Creek, Mud Creek, and Little River which enter from the east, and Davidson River, Mills River, and Hominy Creek which come in from the west. Between Asheville and Marshall, the Ivy River and Sandymush Creek are the main tributaries.

Geology

Geologically the valley of the French Broad presents many striking features common to other streams in the Southern Appalachian Mountains. The stream flows in a geologically complex terrain and has developed a course and valley that deviates widely from the typical or ideal river valley. The Asheville plain, that portion of the French Broad Basin which lies upstream from and south of Asheville, is relatively broad, flat, and open. From sources high in the mountains, the river and its tributaries plunge down steep gradients to the plain where they lose the steepness of their gradients and flow sluggishly to the north. In this section of the basin, the river and its tributaries are flanked by extensive flood plains 10 to 15 feet thick.

From Asheville to Marshall, the river is in a narrow valley 200 to 400 feet deep. Here the flood plains consist of very narrow marginal flats and the tributaries have valleys of V-shaped cross section. The river flows on bedrock, and rapids and ripples are characteristic of the entire section.

The evolution of the present French Broad basin is a fascinating story which is told in Appendix D.

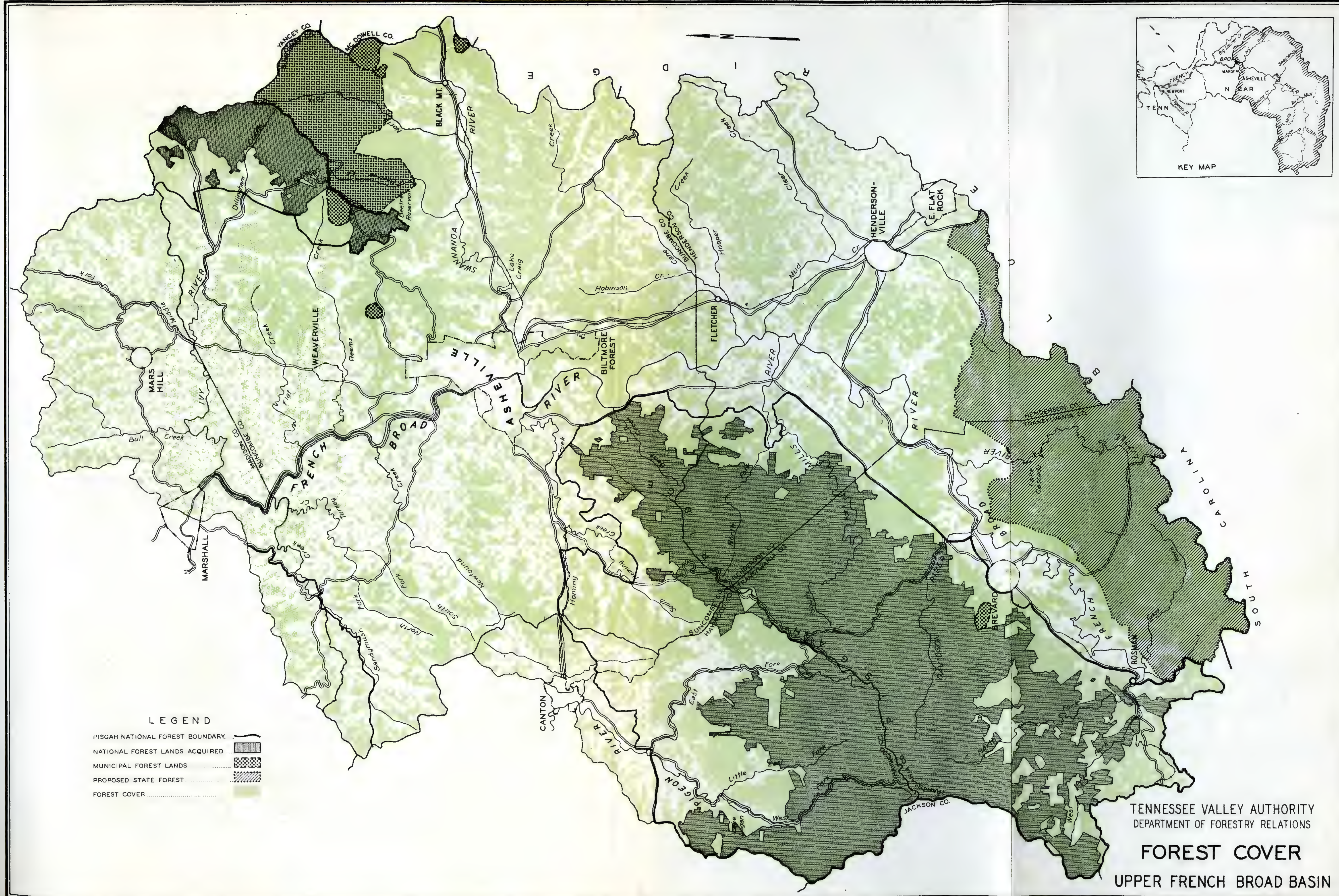
Culture

The principal city in the region is Asheville, population 51,310. Other towns include Hendersonville, population 5,381; Brevard, population 3,061; Marshall, population 1,160. This area, because of its location, climate, and scenic interest, is famous for recreation and vacationing. As a result of this, there is a large transient population throughout the area and many towns double their population during the summer months. Good roads are plentiful. The Blue Ridge National Parkway now under construction follows the mountain divide east of Asheville, crossing the French Broad region just south of Asheville and continues along the high mountains which form the western boundary of the area. The Southern Railway follows generally the course of the river throughout the region with connections to the east and west.

Forests

Of the entire area of 940,000 acres above Marshall and Canton, 629,600 acres, or two-thirds, are in forests. Of this, 224,600 acres are in farm forests, 167,200 in other privately owned forests, 171,000 in national forests, and 33,400 acres in municipal ownership. Plate 2 shows the extent and ownership of present forest cover.

Beginning in the latter part of the 18th Century, areas of forest land were cleared throughout much of the watershed, even to the tops of high mountains in many cases. Some of the steep lands became badly eroded and were abandoned one hundred years ago. Lumbering on a large scale did not begin


LEGEND
PISGAH NATIONAL FOREST BOUNDARY
NATIONAL FOREST LANDS ACQUIRED
MUNICIPAL FOREST LANDS
PROPOSED STATE FOREST
FOREST COVER
KEY MAP
TENNESSEE VALLEY AUTHORITY
DEPARTMENT OF FORESTRY RELATIONS
FOREST COVER
UPPER FRENCH BROAD BASIN
YANCEY CO.
MC DOWELL CO.
BLACK MT.
SWANNANOA RIVER
HENDERSON-VILLE
E. FLAT ROCK
FLETCHER
BILTMORE FOREST
ASHEVILLE
WEAVERVILLE
MARS HILL
MARSHALL
CANTON
BREVARD
ROSMAN
FRENCH BROAD RIVER
PIGEON RIVER
DAVIDSON RIVER
MILLS RIVER
BLUE RIDGE
PISGAH
SOUTH CAROLINA
HENDERSON CO.
TRANSYLVANIA CO.
BUNCOMBE CO.
HAYWOOD CO.
MADISON CO.
JACKSON CO.

until about 1885 when a band sawmill was established on the Vanderbilt Estate at Biltmore.

The national and municipally owned forests are well managed for watershed protection. Management of farm forests varies with ownership. The non-farm areas, which are held for estates and recreational purposes are well protected. Most of the commercially owned forests are not as well protected as other areas.

The first technical forest management in this country began on the Vanderbilt Estate fifty years ago. This area was increased and later became a part of the Pisgah National Forest so that more than 100,000 acres have been protected from fire and destructive logging for many years and furnish first-class watershed protection. Much of the northern portion of the Swannanoa watershed has been used for water supply and recreation, and the protection from fire and excessive cutting has left it in good condition. The Little River and East Fork of Pigeon River watersheds present a great contrast. Soils here were thin originally, and the forests have been devastated and heavily burned for many years, resulting in conditions favorable to large surface runoff. In the remainder of the watershed, forests have been rather heavily cut over but there has been some fire protection.

The watershed from Marshall to Asheville is different from that above Asheville. About 1885, tobacco growing became profitable on the Ivy River watershed and was expanded until large areas of steep slopes were used for this purpose. This was followed by serious soil erosion and eventually abandonment of lands for agriculture. On Sandymush Creek, the hillsides were 40 to 50 percent cleared by 1904, and there was much erosion at that time. The remaining forests have been cut over and burned until they furnish comparatively little watershed protection.

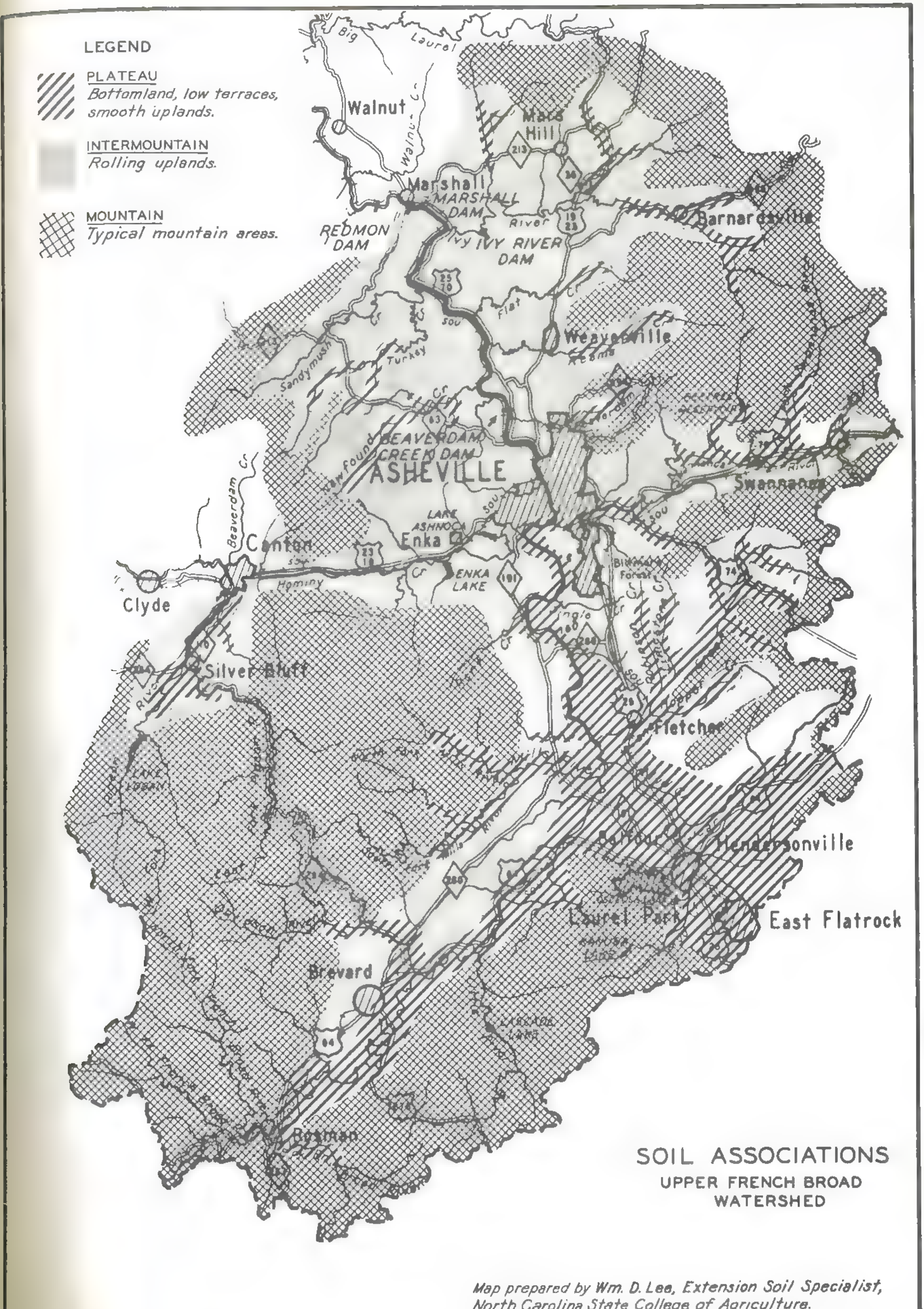
On Pigeon River watershed above Canton, lumbering has been destructive to the forests. In 1925, a severe fire covered some 20,000 acres at the head of the river and destroyed practically all tree growth

and much soil. This area later became a part of Pisgah National Forest, but much of it is still without tree growth. Some 10,000 acres were again burned in the spring of 1942.

Agriculture

Mr. William D. Lee, Extension Soil Specialist, North Carolina State College of Agriculture, describes the area as follows.

> Soil range from brown, mellow silt loam in the bottomlands to red, heavy clays in the intermountain section, to dark brown, friable loams on the higher mountains. Land use varies from intensive truck farming on the broader alluvial areas, through general farming in the intermountain zone, to "patching" with corn on the steep mountain slopes; from poorly-drained bottom-land pastures to well-managed mountain grassland; and from severely cut-over or burned woodland to practically virgin forest areas which have dense ground cover, as in sections of the National Forests.
>
> For a common denominator or equal working basis, lands of the French Broad and Pigeon River basins are placed in three groups (plate 3). To a very large extent these divisions are homogeneous units (although not necessarily contiguous throughout) from the standpoint of topography, soil, and land use, and may be called major soil associations. In this study they are named plateau, intermountain, and mountain.
>
> The plateau group includes those portions of Transylvania, Henderson, and Buncombe Counties where the French Broad and its tributaries have wide bottomlands and terraces; the section along Pigeon River immediately south of Canton; and the central portion of Henderson County which is relatively smooth. The soils of this group are comparatively similar, falling in the alluvial, terrace, and Balfour associations. Erosion is a minor problem. Intensive truck farming is the principal land use of this division.
>
> The intermountain group includes the rolling uplands such as those around Mars Hill, Weaverville, Asheville, Swannanoa--in fact, the greater portion of the inner basin. Soil associations are Hayesville, Fletcher, and Halewood--largely red clays, long-farmed, severely eroded, and presenting a real management problem. General farming is carried on, much of it on steep areas. There is a high percentage of idle croplands, and of land once cultivated, but now partly to well covered with pine woods.
>
> The third, or mountain division, is comprised of the upper reaches of the Pigeon, French Broad, and Ivy Rivers and similar areas. Soil associations are Porters, Ashe, and Ramsey--


LEGEND
PLATEAU
Bottomland, low terraces, smooth uplands.
INTERMOUNTAIN
Rolling uplands.
MOUNTAIN
Typical mountain areas.
Walnut
Mars Hill
Marshall
MARSHALL DAM
REDMON DAM
IVY RIVER DAM
Barnardsville
Weaverville
BEAVERDAM CREEK DAM
ASHEVILLE
LAKE ASHNOCA
Enka
ENKA LAKE
Canton
Clyde
Silver Bluff
Swannanoa
Biltmore Forest
Fletcher
Hendersonville
Laurel Park
East Flatrock
Brevard
Rosman
SOIL ASSOCIATIONS
UPPER FRENCH BROAD
WATERSHED
Map prepared by Wm. D. Lee, Extension Soil Specialist, North Carolina State College of Agriculture.

principally brown to grayish-yellow friable loams. Even though they have rather steep slopes, these soils are not very susceptible to erosion. Individual areas under cultivation are generally small, and the larger portion of the cleared land is in grass for pasture or hay.

These agricultural lands in the French Broad Valley and in the tributary valleys are generally fertile and productive, much more so than the surrounding higher lands which border the river valleys. Farms in this region ordinarily include the bottom lands and the higher lands which rise in some cases quite steeply from the margin of the river valleys. In other parts of the country where there are large flat areas of land, the value of one acre of land is about the same as that of another. In this mountainous watershed, however, this is not the case. According to agricultural authorities, in the farm economy of the region an acre of fertile bottom land is worth several times that of an acre of higher land even under present conditions of flood hazard. The acreage of bottom lands is limited by the width of the river valleys to that immediately along the streams and the total amount of this land is only a small percentage of the area of the region. Because of their productivity, scarcity, and place in the farm economy of each ownership, the bottom lands are in demand and have a high value per acre. County Agent J. C. Lynn of Haywood County states that "in recent years some of the land has been sold at prices ranging from \$400 to \$800 per acre." It is reasonable to assume that lands which now have considerably lower values than these because of flood hazards would be materially increased in value if given flood protection.

Industry

The Upper French Broad region is one which is attractive to industrial development because of the plentiful supply of an excellent quality of water which is desirable for many industries. The water front along the French Broad River through Asheville and the Biltmore to Azalea section along the Swannanoa River are highly developed for industries and commercial establishments. Outside of Asheville there are three very large industrial plants in the watershed, all of which are subject to flood

damage. These are the American Enka Corporation rayon plant on Hominy Creek, the Ecusta Paper Corporation plant on Davidson River near Brevard, the Champion Paper and Fibre Company's plant on Pigeon River near Canton.

Rainfall

Annual rainfall over the Upper French Broad watershed varies from 40.3 inches at Asheville to 73.2 inches at Rosman in the upper end of the watershed. The high mountains and general topographic features of the region definitely influence the amount and distribution of rainfall throughout the various parts of the basin. The heaviest rainfall region is generally in the mountains on the south and west of the watershed. The reach from above Asheville to Marshall is a comparatively low valley sheltered by mountains and higher lands and has an annual rainfall considerably less than the area immediately to the south. For example, Hendersonville, only 25 miles south of Asheville, has an annual rainfall nearly 20 inches greater than Asheville.

The entire region is subject to intense and heavy rainstorms that result in severe floods. Twenty or more percent of the annual rainfall may occur in a storm lasting only a day or two. These storms may be either of tropical hurricane origin or of summer thunderstorm characteristics. The mid-August 1940 storm was of the former type and the late August 1940 storm was of the latter. The great 1916 flood was caused by a tropical hurricane which swept in from the North Carolina coast.

The violent hurricane type storms are likely to cover large areas with several "high spots" of rainfall. The summer thunderstorms tend to strike smaller areas which, however, may be as big as the watersheds of many of the French Broad tributaries. Both storm types precipitate large volumes of rain in relatively short times of from half a day to perhaps two days. In 1916, rainfall at Altapass near Asheville was 22 inches in 24 hours. In August 1940, amounts in excess of 15 inches in a day occurred at several places. The meteorology of these storms together with a discussion of maximum probable rainfall in the French Broad region is given in Appendix C.

Floods of the Past

Whenever intense storms occur, floods result, sometimes over the whole watershed, sometimes over only a part or parts of the watershed. On the headwaters of the French Broad and on the mountain tributaries, floods rise rapidly to sharp crests of short duration. Along the French Broad Valley above Asheville where stream slopes are relatively flat, floods remain longer above bankfull stages.

Stream flow records have been maintained which furnish information on floods in recent years such as those of 1916, 1928, and 1940. Research has uncovered knowledge of early floods on the main river and on the tributaries which reached heights comparable to or in some cases exceeding those of modern floods. Such floods did little damage when they occurred because the country was in a pioneer state of development. If these floods were to recur, damages to present developments would be considerably greater. Accounts of both old and modern floods on the main river and the chief tributaries are given in Appendix A.

Development Retarded by Floods

The effect of floods in the French Broad region is apparent in that the development of the region, both industrially and agriculturally, has been retarded by the menace of floods.

Industry--At Asheville, industrial establishments on the main river suffered heavy losses in the 1916 flood from which the area has never recovered. A number of concerns have gone out of business and there has been little expansion since that flood. The occurrence of the 1928 and 1940 floods has further added to the fear of floods with consequent stagnation of development and decrease in property values.

Through the Biltmore section of Asheville on the Swannanoa River, the story is much the same. That area had considerable losses in 1916 but did not reach its greatest development until between 1916 and 1928. The

flood in 1928 and the two in 1940 caused huge losses to industries and commercial establishments. This has resulted in a setback to the area by stoppage of industrial expansion. The property has also suffered large deterioration in value.

Agriculture--Agriculture on the fertile flood plain lands is faced with the constant hazard of large summer floods. Were it not for this, many of these lands, according to County Agent J. A. Glazener of Transylvania County, would be converted into truck crop lands of high productivity and value. Under existing conditions, it is hazardous to grow truck crops with the possibility of large losses in case of flood. Consequently, corn is grown on many acres of land that would be attractive for growing truck crops if these lands are protected from floods.

Flood Damages

It is estimated that the floods which have occurred in the French Broad River Basin over the period 1875 to 1940, if repeated with development conditions as they are in 1941, would cause total damages of $13,600,000. A repetition of the July 1916 flood would result in damages of nearly $5,000,000. A repetition of the August 1928 flood would result in damages of about $680,000. Repetition of the two August 1940 floods would cause damages estimated at about $1,720,000.

Of the total estimated damages, 36 percent represents industrial damage, 28 percent agricultural damage, 14 percent damage to railroads, and 6 percent damage to highways. Ten percent of the amount represents land and property devaluation in the industrial areas in Asheville and Biltmore.

Without flood protection, the city of Asheville and the Upper French Broad Valley is certain to sustain huge flood losses in every major flood. Almost every year, the agricultural region sustains losses from floods which would do little damage if controlled.

FIGURE 2 — ASHEVILLE WATER FRONT AUGUST 30, 1940

Industries along the right bank of the French Broad in Asheville were flooded about the same amount by both August 1940 floods. Flood of July 1916 was 11 feet higher resulting in much greater damages.

Flood Protection Plans

Future Maximum Flood

It is probable that in the future there will be greater floods than those which are known to have happened in the past. With development as it is today, a flood greater than that of July 16 over the French Broad watershed or one greater than that of 1791 on the Swannanoa watershed would cause tremendous damages. The possibility of such floods must be provided for in flood protection for this region.

Because of the large damages which were caused to industries, railroads, highways, farms, municipalities, and other classes of property in the French Broad region during the great flood of July 1916, such a flood is likely to be thought of by those not skilled in flood control engineering as unlikely to be exceeded. However, taking into consideration the location of the French Broad watershed, its geographic position with respect to storm paths, its topography and range of elevations, it is believed that a flood approximately 50 percent greater in peak rate could occur at Asheville. Such a flood would have a peak discharge rate of 154,000 cubic feet per second and would be approximately 5 feet higher at Asheville than the 1916 flood. Damages throughout the French Broad region would be of the order of $8,000,000 or perhaps more.

In connection with the development of plans for flood control, a hypothetical rain storm has been worked out covering the Upper French Broad watershed which would produce an uncontrolled flood of maximum proportions at Asheville. This storm is discussed in Appendix C and is shown on the isohyetal map, plate 47. Meteorologists Kleinsasser and Younkin, U. S. Weather Bureau, Knoxville, collaborated in working out the maximum storm. Compared to the great 1916 flood, the hypothetical maximum storm provides a margin of about 50 percent in both peak rate and volume of surface runoff.

the city of Asheville and the valley of the Upper French Broad and its tributaries as one region to be taken as a whole in the development of a flood protection plan. The second provides protection for Asheville only. In the latter case, the desirability from a regional development standpoint of protecting as much as possible of the agricultural area in the valley of the Upper French Broad and its tributaries would be ignored.

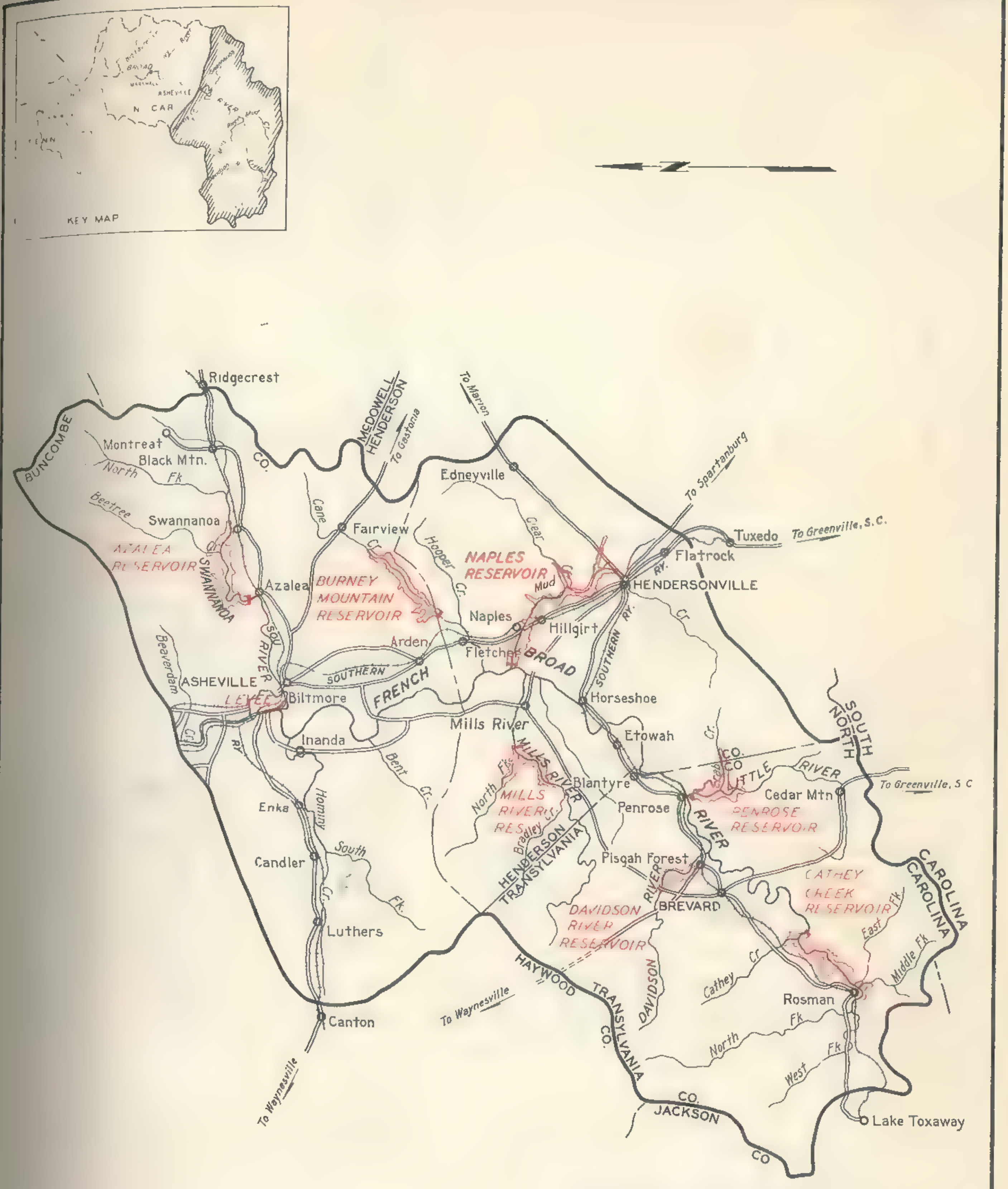
Methods of Flood Protection

The chief means of flood control are storage reservoirs, levees, and channel improvements or some combination of these. A study of the flood problems of the French Broad region shows that the main part of a flood protection plan for Asheville and the agricultural lands must be storage reservoirs located on the watershed upstream from Asheville. These in turn must be supplemented by levees at Asheville and by some minor channel improvements. At Canton, Marshall and Hominy Creek local works, principally levees, appear to be the best means of protection.

Regional Plan for Flood Protection

To provide flood control for both urban and rural areas on a regional basis, including the city of Asheville and the Upper French Broad valley, a plan has been developed, the principal features of which are shown on plate 4. This includes seven storage reservoirs of the detention basin type, a levee at Asheville, and some minor channel improvements on the Swannanoa and French Broad Rivers. Table 1 gives pertinent data regarding the reservoirs. The plan provides complete protection for Asheville and agricultural protection as previously defined for the valley lands.

The storage capacity of each reservoir has been planned consistent with the degree of flood protection desired from each reservoir. The Azalea Reservoir on the Swannanoa River is designed with a storage capacity at the level of the spillway of 12 inches of runoff from the tributary drainage area in order that the valuable industrial and commercial district in Biltmore would never be damaged by Swannanoa River floods. The storage reservoirs on



TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

PROPOSED

REGIONAL PLAN FOR FLOOD CONTROL

UPPER FRENCH BROAD RIVER BASIN

SCALE 0 5 10 15 MILES

TABLE 1

STORAGE RESERVOIR DATA

The Regional Plan includes all reservoirs except Britton Mountain.
The Asheville Only Plan includes Azalea and Britton Mountain Reservoirs.
Data are preliminary and subject to change in final design.

Reservoir	Drainage Area Sq.Mi.	Dam			Storage Capacity		Area		Outlet Conduit Capacity c.f.s.	Spillway Capacity at 10 Ft.Depth c.f.s.
		Type	Maximum Height Feet	Total Length Feet	At Spillway Crest 1000 Ac.Ft.	At Top of Dam 1000 Ac.Ft.	At Spillway Crest Acres	At Top of Dam Acres		
Azalea (Swannanoa R.)	96	Earth & Rock	142	1,140	62	87	1,520	1,900	2,000	12,500
Burney Mountain (Cane Creek)	60	Earth	68	1,580	17	36	820	1,370	5,000	16,000
Naples (Mud Creek)	113	Earth	49	1,610	24	67	1,960	3,900	9,000	33,000
Penrose (Little River)	60	Earth	58	1,370	19	38	1,080	1,500	5,000	16,000
Catheys Creek (French Broad R.)	131	Earth	71	1,380	41	88	2,350	3,070	10,500	25,000
Davidson River	41	Earth & Rock	92	550	13	20	360	430	4,700	8,600
Mills River	67	Earth & Rock	90	1,800	21	35	780	980	5,500	14,700
Britton Mountain	664	Concrete	70	1,000	214	458	12,600	20,200	40,000	55,000

Cane Creek, Davidson River, Mills River, Little River, and the French Broad River near Catheys' Creek are each planned to have a storage capacity at spillway level of 6 inches from the tributary watersheds. These reservoirs are designed both to provide agricultural flood protection to the Upper French Broad and tributary valley lands and also to store a considerable part of the flood runoff during great floods, thereby reducing the magnitude of such floods at Asheville. The capacity of 6 inches provides adequate control for all except the great floods. During those great floods, the spillways of some, but probably not all, of these storage reservoirs would come into action.

On Mud Creek, the Naples storage reservoir has a capacity of 4 inches of runoff from the watershed. It is not possible to obtain more storage in this reservoir without flooding part of the city of Hendersonville, which it was not desired to do.

Along the right bank of the French Broad River through Asheville, an earth levee is proposed to be constructed. This levee in combination with the storage reservoirs would provide complete protection to the principal industrial and commercial area along the French Broad water front through Asheville. The grade line for the top of the levee has been fixed so that it is 2 feet above the water surface for the outflow from all of the upstream storage reservoirs plus the runoff from the uncontrolled areas during maximum floods. In recognition of the improvement that is contemplated to be made in the cover on agricultural and forest lands upstream from Asheville through improved land use in the next twenty years, the height of the levee has been reduced one foot. The basis for this is discussed in a later section of this report and in Appendix F.

In order to provide capacity for runoff from the part of the Swannanoa River watershed below the Azalea Reservoir, it is proposed to improve the river channel to some extent from its mouth upstream for about seven miles. This work would consist principally of clearing and minor work in the channel. It is also proposed to improve the channel of the French Broad River from Asheville upstream to near Brevard by similar work.

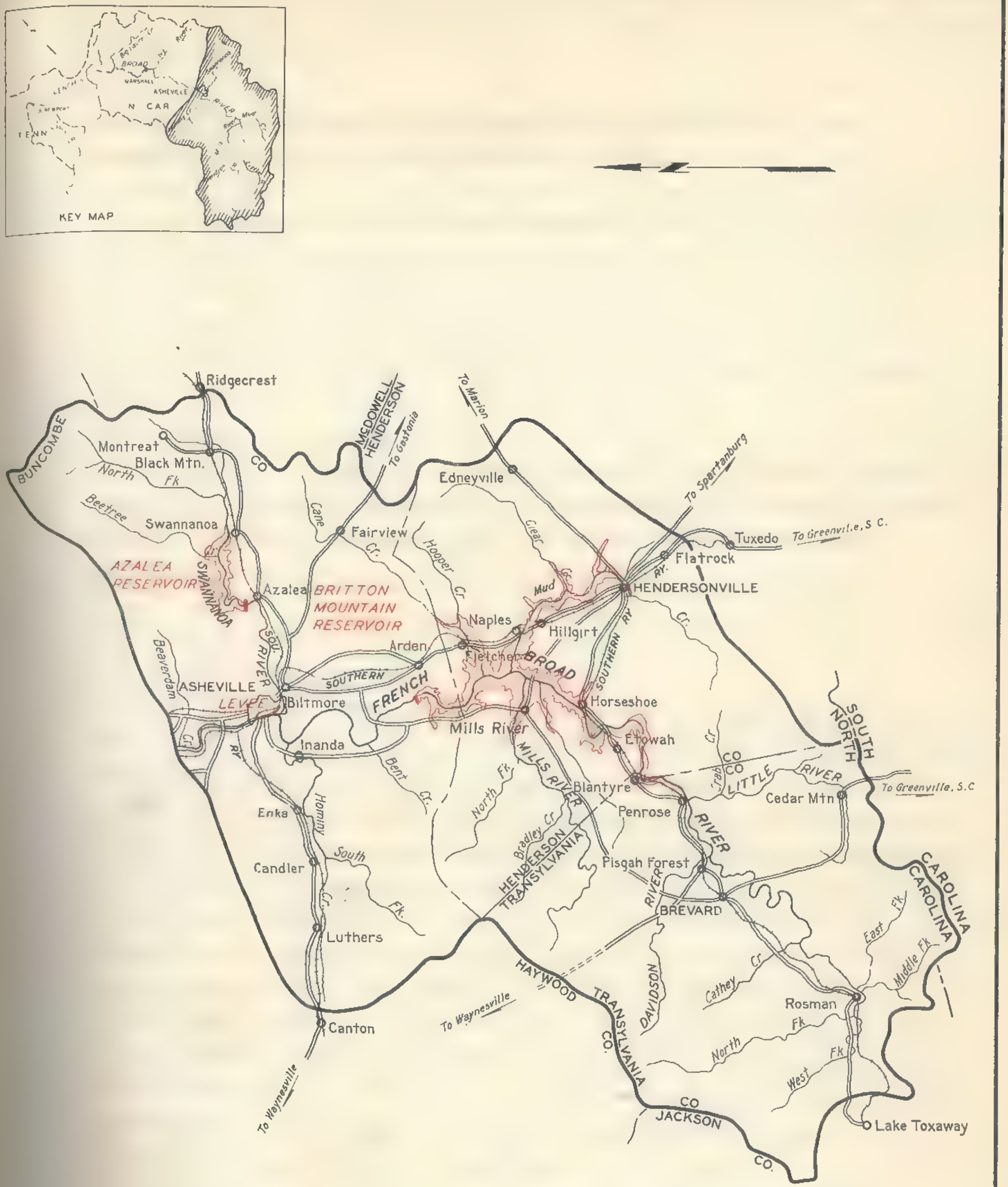
The storage reservoirs which are included in this plan are all of the detention basin type which is described more fully in a later portion of this report. These reservoirs are so designed that they store water only during a flood and release this following the flood. Normally the reservoir areas are dry and may be used for farming or other purposes.

The dams which create the storage reservoirs all have spillways and outlet conduits for the discharge of water. Neither time nor data has been available for the complete detailed study which is necessary to fix the exact height of the Asheville levee and to provide the best balance and coordination of storage, spillway and outlet capacities for the several reservoirs which together make up the Regional Plan. Such study should be given prior to the final adoption and construction of the proposed works.

Asheville Only Flood Protection

To provide flood control for the industrial and commercial areas in Asheville including those in Biltmore on the Swannanoa River but not protecting any of the agricultural valley lands, the plan shown on plate 5 has been prepared. This includes two storage reservoirs of the detention basin type, a levee through Asheville and the improvement of the Swannanoa River channel. Table 1 gives pertinent data regarding the reservoirs.

The Azalea Reservoir on the Swannanoa River under this plan would be the same as that under the Regional Plan because this is necessary to completely protect Biltmore from Swannanoa River floods. The second storage reservoir is located on the main French Broad River twelve miles upstream from Asheville at the Britton Mountain site. For a single reservoir to control French Broad floods originating upstream from the mouth of the Swannanoa River, this reservoir should be located immediately upstream from Asheville, in order that the reservoir may catch the flood runoff from any part of the 650 square miles of upstream drainage area and control this regardless of its origin. Storage capacity at the elevation of the spillway amounting to 6 inches from the upper watershed has been planned for this reservoir. Through the dam are uncontrolled outlet conduits purposely



TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

PROPOSED

FLOOD CONTROL PLAN FOR ASHEVILLE ONLY

UPPER FRENCH BROAD RIVER BASIN

SCALE 0 5 10 15 MILES

designed with large capacity in order to limit the extent of flooding of lands in the reservoir except during large floods.

The levee along the French Broad water front at Asheville in this plan would be slightly lower than that under the Regional Plan. The grade line has been planned to carry with a margin of 2 feet the outflow from Britton Mountain and Azalea Reservoirs plus the runoff from the uncontrolled areas during maximum floods. Improvements in the Swannanoa River channel would be the same as those under the Regional Plan.

Before construction of the works included in this plan, further study should be given to the balancing and coordination of storage, spillway, and outlet capacities for the reservoirs and to the grade line for the Asheville levee.

Plan for Marshall

The town of Marshall which is subject to overflow from the French Broad would be benefited as a result of the reduction of flood heights under either the Regional Plan or that for Asheville Only. However, the uncontrolled drainage area of nearly 400 square miles between Asheville and Marshall is capable of producing large floods. This would make it necessary to construct local protection works at Marshall. Since the flood plain at Marshall is practically all occupied by buildings, streets and railroad tracks, there is insufficient room for an earth levee. Protection could be secured by a concrete levee along the river front through the town. The cost of such a levee to a height equal to that of the maximum flood would be high in relation to the benefits. For this reason, three alternative plans have been made, one to protect against maximum floods, one to protect against floods of the height of the late August 1940 flood, the other against floods equal to that of July 1916.

Plans for Hominy Creek and Pigeon River

These areas have flood problems which are directly related to each particular stream and which are not common to the remainder of the

region. Flood protection for these two basins, therefore, resolves into such works as may be necessary to protect properties which are subject to flood damages in each particular basin.

In the case of the Hominy Creek Basin, a plan has been worked out for the protection of the industrial property of the American Enka Corporation plant against maximum floods. This plan includes raising and extending the existing levee system around the Enka plant.

On the Pigeon River, it has not proven feasible to provide protection for agricultural lands in the basin but two plans have been prepared by which the industrial and commercial properties in Canton where large damages occur would be protected by levees along the river through the city. These plans give protection against floods respectively 5 feet and 10 feet above the late August 1940 flood. Some channel improvements could be made which would improve flood conditions for agricultural lands.

Outlet Works and Spillways

There would be an outlet conduit through each dam to pass the natural stream discharge and to empty the reservoir after each flood. Excepting for the reservoir on the Swannanoa River, there would be control gates on the outlet conduits to regulate the flow through the conduits so that the reservoir could be operated effectively both for large and small floods and could be quickly emptied after each flood. During ordinary floods, the outflow from the conduit would be restricted to not more than the capacity of the stream channel downstream from the dam so that the valley lands would be protected from overflow.

In the case of the Azalea Reservoir on Swannanoa River, there would be no gates on the outlet conduit and this would operate entirely automatically. The outflow from the conduit is planned not to exceed the river channel capacity downstream and to be large enough to empty the reservoir after each flood to make storage capacity available for subsequent floods should these occur.

To provide for the safety of the structures and for the possibility of flood runoff in excess of the storage capacity of the reservoir, a spillway is provided at each dam with a crest 15 feet below the top of the dam. Surplus flood waters would discharge over the spillway into the stream below each dam.

Under the Regional Plan, with the exception of the reservoir on the Swannanoa River, it is contemplated that at long intervals of time there may be large floods which will exceed the storage capacity of some of the reservoirs. During such floods, the outlet conduits would be opened to full capacity. Surplus flood water in excess of the capacity of the outlet conduit and the storage capacity for any reservoir would flow over the spillway and discharge back into the stream below the dam. The large storage capacity of the Azalea Reservoir makes it doubtful that there would ever be any flow over the spillway.

Reservoir Adjustments

Some adjustments will be required in the highway systems within each reservoir area. However, the highways would be affected only for a few days at comparatively long intervals of time and would not be interfered with sufficiently to justify relocation. All buildings below the maximum water level in each reservoir would be removed. Timber within the reservoirs would not be cleared.

Designs Preliminary

Only limited investigations of dam sites and locations for local protection works have been possible within the time available for the preparation of this report. Designs for structures are therefore preliminary but are sufficient in each case for estimating costs and indicating in a general way the character of the proposed works.

The sites for all of the proposed dams have been examined by the Authority geologists and are reported upon in Appendix D. Further geologic

explorations accompanied by core drilling would be necessary before final plans are prepared in order to determine accurately foundation conditions at each site and the materials available for construction.

It is contemplated that prior to construction, complete and detailed information regarding each dam site would be obtained. Similar information would be secured for local protection works. The final design for each structure would be made after this detailed information has been obtained.

Progressive Reservoir Construction

The Regional Plan for flood control lends itself to construction of the various reservoirs progressively if such a plan should be deemed desirable. On this basis, the reservoirs should probably be constructed in the following order:

1. Azalea Reservoir on Swannanoa River because of its importance in reducing floods through the industrialized Biltmore section of Asheville.

2. Mills River Reservoir because of providing protection for the rich agricultural lands along Mills River and in the French Broad Valley.

3. Burney Mountain Reservoir on Cane Creek because of protection of Asheville and Hendersonville Airport and agricultural lands along Cane Creek and in the French Broad Valley.

4. Davidson River Reservoir because of protection against large floods to the Ecusta Paper Corporation plant.

5. Cathey Reservoir on the Upper French Broad.

6. Naples Reservoir on Mud Creek.

7. Penrose Reservoir on Little River.

This order is not an inflexible one for conditions may change which might make it desirable to build the reservoirs under a different program in case they should not all be built at the same time.

For the Asheville Only Plan, there would be little choice as to whether the Azalea Reservoir on Swannanoa or the Britton Mountain Reservoir on the French Broad were built first.

In the case of either plan, the levee at Asheville on the French Broad water front might be built at any time during the execution of the complete plan. However, should the levee be built before the reservoir system has been finished, there would be danger of the levee being overtopped by a flood which could not be controlled by an incomplete reservoir system. Because of its comparatively low costs it might be worth while to take the risk of overtopping for the partial protection afforded. In such an event, there is always the danger of a sense of false security arising should the levee not be overtopped for a considerable period of years.

Operation Under the Regional Plan

Detention Reservoirs

Each of the storage reservoirs is of the type known as detention basins. This means that water would not be permanently stored but that ordinarily the reservoirs would be empty. Whenever a flood occurs, water would be stored during the flood and would be released through the dam in harmless quantities after the flood. The reservoir would thus be emptied within a comparatively few days. There would be some lands along the sides of the reservoir not previously subject to overflow which would, during extreme floods, be covered with water for a short time while the reservoir was in use. In general, it would be possible to continue the use of the lands within the reservoir for general farming purposes.

With regard to the effect of impounding flood water in the detention storage reservoirs, Mr. William D. Lee, Extension Soil Specialist, North Carolina State College, states as follows in the pending report "Land Cover and Its Relationship to the Control and Utilization of Water in the Upper French Broad River Watershed."

Actual benefit to the soil, or damage to crops, will depend upon the length of time water remains impounded. The longer this period the greater the amount of deposition of silt and clay, and the greater the damage to crops. A study was made of the character and depth of material deposited by the August 1940 flood. The deposition ranges from a thin coating of silt and clay to great piles of sand, gravel, and boulders. With a reservoir system the sand and other coarse material would be dumped along the channel usually near the upper limit of the impounded water, while the finer material would be carried farther down. Under the relatively still water considerable soil would be deposited. Its character will be dependent largely upon the type of watershed above. The beneficial values assigned to the land from deposited material were determined by comparing a few low-lying fields having the same soil characteristics. The fields in the comparison are not fertilized, and the apparent gain from the deposited silt in the flooded areas is equal in one season to the average application of fertilizer (worth about $3.00 per acre) - corn being the crop. Under the reservoir system this value would be greater.

Within a reservoir damage to land from scouring, channel cutting, and streambank erosion would not be severe. Growing crops, on the other hand, could not escape serious injury since they would be covered for some time. In most cases such vegetation as corn, small grain, truck and like crops, would be largely or totally destroyed even if inundated less than a day. Hay crops would not suffer as severely, and pastures probably would not be damaged appreciably. It is assumed that water would remain impounded for at least a sixteen-hour period. Within each of the proposed impounding reservoirs regular farming operations could be carried on just as if there were no dam on the stream. All farmers tilling land along the streams of the mountain area of the State "take a chance" each year. Roughly speaking, about one crop out of four is damaged by flood waters. There is no reason to believe that flooding would be any more frequent under the reservoir system. It would simply cover more territory, be complete, and often destroy the crop except in case of pastures and some of the plants grown for hay. Actual damage to land in the lower limits of the reservoir by scouring, bank cutting, or deposition of gravel and sand and the like would be almost entirely eliminated. Even though the crop were lost, the soil would not be gone, but in all probability improved to some extent by silt and clay laid down under the comparatively still water.

Control and Operation During Floods

The operation of the system of reservoirs designed for the protection of Asheville and the agricultural area should be controlled by the skilled and experienced staff of hydraulic engineers of the Tennessee Valley

Authority as an integral part of the water control and dispatching operations for the entire TVA reservoir system. These engineers through a cooperative service with the U. S. Weather Bureau receive twice daily, or more often during storm periods, forecasts of weather conditions, and probable rainfall. Communications should be established throughout the watershed so that amounts of rainfall are known quickly while rain is falling and after it is over. Utilizing this knowledge of rainfall and stream flow conditions throughout the entire Upper French Broad region, the hydraulic engineers would determine how the outflow from each reservoir should be controlled so that the maximum benefit to the French Broad Valley and to Asheville would be received during floods of all sizes.

Operation for July 1916 Flood

This flood, as has been previously stated, was the largest known flood throughout the Upper French Broad region. Should such a flood recur after the construction of the Regional Plan, the height of the flood throughout the Upper French Broad Valley would be lowered by approximately 8 feet on the average. Although there would be some overflow of bottom lands, the extent of the overflow would be considerably reduced below that which actually occurred in 1916. At Asheville, the height of the flood would be reduced so that it would flow past the city with a considerable margin below the top of the proposed levee along the French Broad River.

In the operation of the Regional Plan reservoir system during a flood of this or greater magnitude, the outlet conduits through the dams which are provided with control gates would be closed during the early part of the storm. As soon as the storm had developed sufficiently so that the hydraulic engineers operating the system could determine that a great flood would take place, then the outlet conduits would be completely opened. In such a flood, the agricultural lands would not receive protection other than the reduction in stage that would occur throughout the valley. Asheville with its levee would receive complete protection.

Operation During Mid-August 1940 Flood

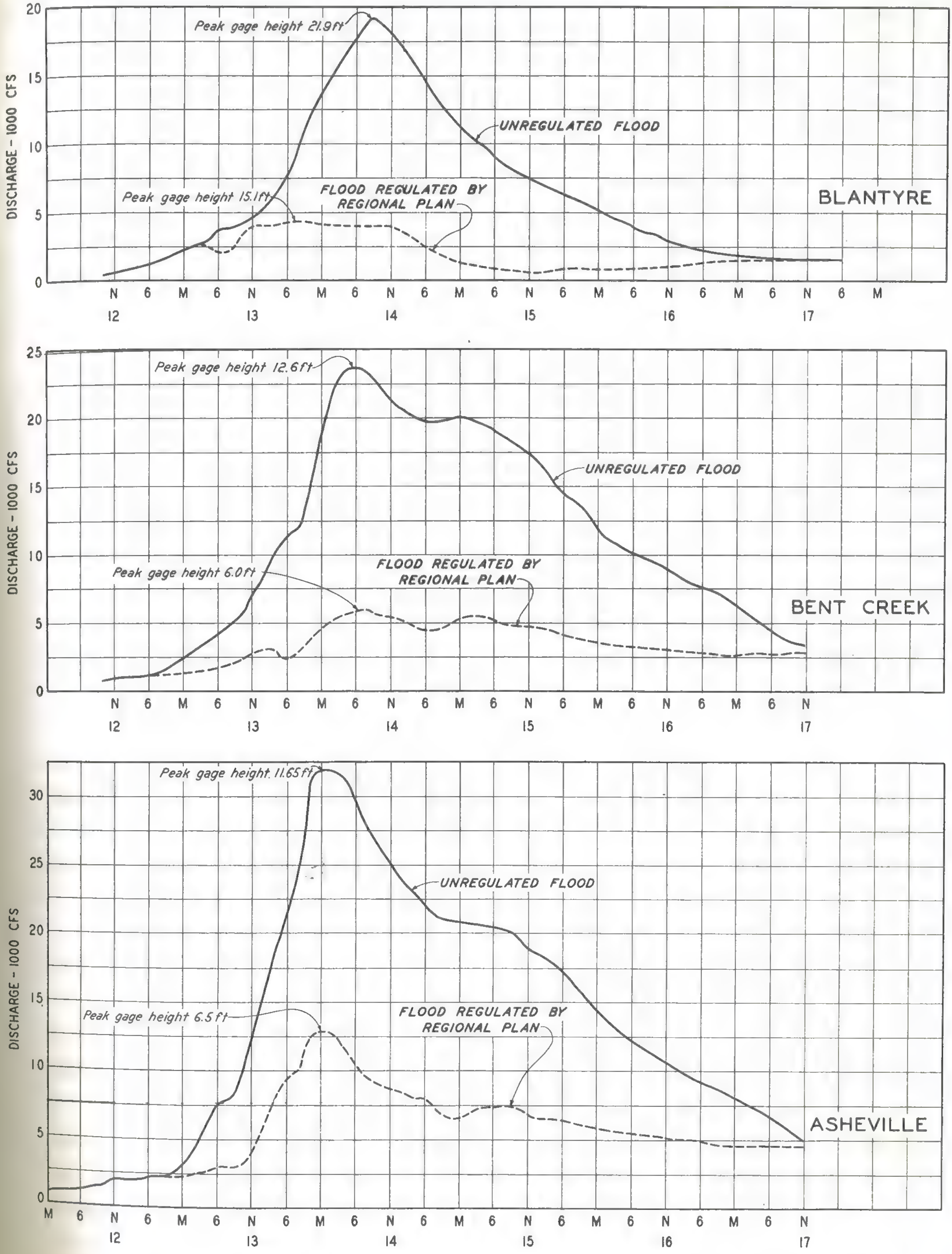
The regulation of this flood which would be accomplished by the Regional Plan system of reservoirs at Blantyre, Bent Creek, and Asheville is shown on plate 6. The height of the flood throughout the French Broad Valley would be reduced by an average of about 6 feet. This reduction would greatly reduce the losses that would otherwise occur during such a flood. However, the flow during this flood after regulation by the reservoirs would be sufficient to cause the river to overflow its banks by about 1 to 2 feet. Through Asheville the regulated flood would be about 16 feet below the top of the proposed levee.

During such a flood, the outlet conduits through the reservoirs where the conduits are provided with control gates would remain closed throughout the flood in order to hold back as much flood water as possible so that maximum protection would be given to the agricultural lands. Following the flood, the gates would be opened and the storage water released at rates which would not be harmful.

The 1940 mid-August flood is just slightly larger than those floods which can be controlled without overflow by the Regional Plan. On the basis of the past history of floods at the Blantyre stream gage, it appears that only one flood in 12 or 13 years would overflow the banks of the French Broad throughout the valley.

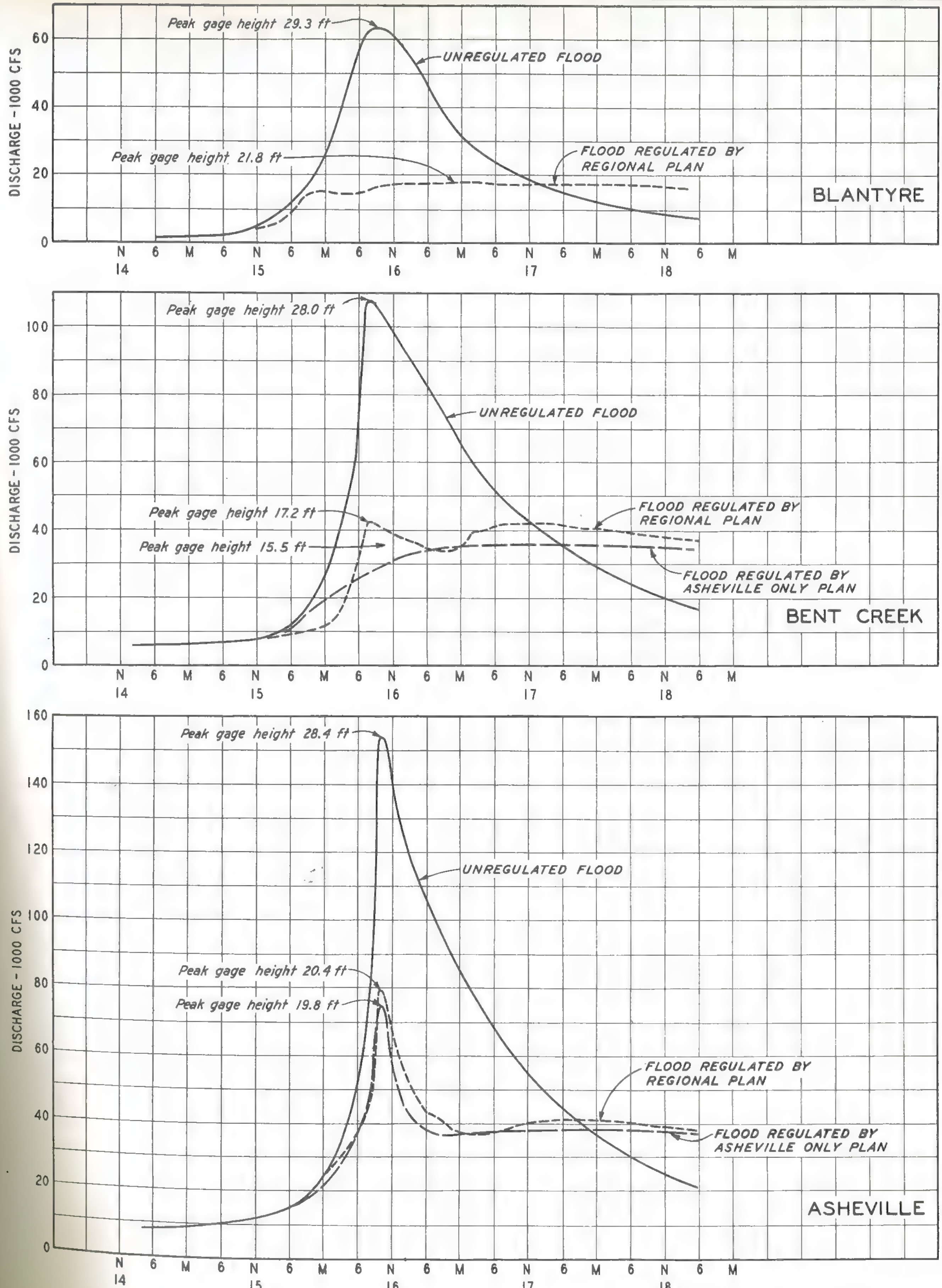
Operation for Maximum Flood

Plate 7 shows the reduction by reservoir regulation of the flood which would be produced by the hypothetical maximum storm at Blantyre, Bent Creek, and Asheville. Under the Regional Plan the operation during the maximum flood would be similar to that described for the flood of July 1916. The flood runoff in excess of that stored under either the Regional Plan or the Asheville Only Plan would flow past the city of Asheville 2 feet below the top of the proposed levee.



TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

COMPARATIVE HYDROGRAPHS
MID AUGUST 1940 FLOOD
FRENCH BROAD RIVER



TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

COMPARATIVE HYDROGRAPHS
HYPOTHETICAL DESIGN FLOOD
FRENCH BROAD RIVER

Silting of Reservoirs

Investigation has been made of the probability of silting in the proposed detention reservoirs. The volume of deposition that would occur in each of the reservoirs is very small in relation to the reservoir capacity in each case and indicates that the reservoirs would retain their usefulness in fulfilling their intended purpose for centuries. The greater part of the silt deposited on the lands within the basins would be fine grained and should add to the fertility of the soil. In this connection, the experience of the Miami Conservancy District in Ohio during more than twenty years of operation, is that the silt deposits during flood times have increased the fertility of the farm lands within the retarding basins in that District. The amount of the deposits has been small and has not materially reduced the basin capacities.

Cost of Flood Protection Plans

The following are summaries of the cost of the principal items in the flood protection plans. Details of the estimates showing items of work are given in Appendix E.

Regional Flood Protection Plan

Azalea Reservoir on Swannanoa River	$1,350,000
Burney Mountain Reservoir on Cane Creek	1,225,000
Naples Reservoir on Mud Creek	1,135,000
Reservoir on Mills River	1,100,000
Reservoir on Davidson River	790,000
Cathey Reservoir on Upper French Broad River	1,275,000
Penrose Reservoir on Little River	725,000
French Broad River Levee at Asheville	510,000
Swannanoa River Channel Improvement	50,000
French Broad River Channel Improvement	50,000
Total	$8,210,000

Flood Protection Plan for Asheville Only

Azalea Reservoir on Swannanoa River	$ 1,350,000
Britton Mountain Reservoir, French Broad River	3,000,000
French Broad River Levee	403,000
Swannanoa River Channel Improvement	50,000
Total	$ 4,803,000

Flood Protection for Marshall

Alternate Plans for Concrete Levee along the French Broad River:

A. For Complete Protection	$ 767,000
B. Protection Equal to 1916 Flood	516,000
C. Protection Equal to 1940 Flood	297,000

Flood Protection for Hominy Creek

Raising and Extending Existing Earth Levee at American Enka Corporation Plant	$ 114,000

Flood Protection for Canton

Alternate Plans for Earth Levee along Pigeon River:

A. Protection 10 Feet Above 1940 Flood	$ 172,000
B. Protection 5 Feet Above 1940 Flood	101,000

Benefits

The appraisal of the value of flood protection requires the consideration of floods which have occurred and are likely to occur, the consideration of past actual damages, the determination of damages which are likely to occur, and an estimate of benefits to be obtained.

It has been a common mistake to consider the effect of floods in too narrow a way. The National Resources Committee, in its report to the President of the United States regarding flood control for the city of Chattanooga, called attention to the necessity of taking "properly into

account social benefits as well as economic benefits, general benefits as well as special benefits, potential benefits as well as existing benefits," and further stated with reference to certain benefits which were not easy to determine, that "their intangible nature will not justify their neglect."

Interest in flood control in the Upper French Broad River is by no means limited to the city of Asheville nor to the area actually reached by floods, although all the fertile bottom land of this region is visited by destructive floods. The future development of the region will be affected by flood conditions on the land actually inundated. Property values in the areas outside of the flood zones are dependent upon the economic welfare of the industries and farm lands subject to flood. Farm lands above overflow are in general of low producing power and require the products of the adjacent valley lands in their existing agricultural operations.

Asheville, the largest city in western North Carolina, is the trade center and transportation center of a region which is capable of extended development because of its many resources including abundant water, good soil, extensive forests, and a climate without extremes of heat and cold.

A number of industries now in the valley have not expanded their plants to the original plans because of floods experienced after the first units were put into operation.

The flood hazard to the farm lands is definitely known and greater floods than those experienced within the past century would not involve additional large areas, nor would the damage to crops be much greater than that of record. The damage from floods greater than those of record to industrial and commercial property would be a different story. Increased flood heights would affect many additional properties and result in disaster to plants subject to serious damage by only moderate floods. After great floods, threat of further damage has been sufficient to prevent new investment or rebuilding of the structures destroyed. For example, the plant of the Carolina Machinery Company destroyed by the 1916 flood in Asheville was not rebuilt.

The expenditure for flood control which may be justified depends both on the amount of flood damage which could be prevented and the benefits resulting. Certain of these benefits result directly from the prevention of damage. Others arise from resulting new development within the flooded area, with increase in value and population that would otherwise not occur.

The studies made of flood damage to all sorts of property show that a repetition of the record flood of 1916 would cause a loss of about $5,000,000 to the region as now developed. This figure covers only tangible loss. Intangible losses would add materially to the total. A flood five feet higher than the stage reached in 1916 is believed to be possible. Such a flood would cause a loss estimated to be at least $8,000,000. Many of the ill effects suffered from such a great flood would be permanent certainly as far as the present inhabitants are concerned. Serious declines in value of industrial sites occurred after the two floods of August 1940.

The aggregate benefits to the city of Asheville from flood protection would certainly be far greater than the possible direct loss from the largest flood to be expected. An expenditure for flood protection larger than the direct loss would be fully justified. The cost of such work could be repaid over a period of years, while a sudden great loss from a flood would find many property owners unprepared to meet it.

Benefits of Regional Plan

The benefits of the Regional Plan for Flood Protection would include not only those accruing to Asheville but would extend to about 10,000 acres of highly fertile bottom land now subject to floods and to additional roads, railroads, industries, and the Asheville and Hendersonville Airport.

It is the opinion of agricultural authorities that the bottom lands have peculiar and unusual advantages for the profitable production of truck crops of high acreage value. Lands now mostly in general field crops such as corn and hay because of the flood hazard have demonstrated that when not

affected by floods they can produce a wide variety of truck crops having many times the value per acre of general field crops. Similar lands in this general region which are free from floods have sold at prices ranging from $400 to $800 per acre. It appears reasonable to expect that these valley lands would, when protected, have an increase in value of $300 per acre. For the benefited area of approximately 10,000 acres, the total benefits would be about $3,000,000.

If "potential benefits" are considered, as suggested by the National Resources Committee, then the benefits to agricultural lands are considerably greater than the increase in land values. Damages on the agricultural lands in the Upper French Broad alone, not including the tributaries, indicate that a repetition of the floods for the past 65 years with development conditions as they were in 1941 would result in total damages in excess of $2,000,000 with an average annual damage of approximately $30,000. In 1941, the greater part of the lands were being used for corn with only a limited acreage in valuable truck crops. With agricultural flood protection, agriculturists agree that the majority of the lands would be converted into truck crop production in which case the per acre value of crops would be on the average about ten times the average value of crops being grown on the lands in 1941. On this basis, the potential annual losses would be in the neighborhood of ten times those which would occur for development conditions similar to those in 1941. For the 65-year period, these losses would be $20,000,000 and the average annual damage would be $300,000. Capitalizing the potential annual damage at 3-1/3 percent, the resulting benefits would be $9,000,000. Reducing this for the occasional losses which would occur under agricultural flood protection, the resulting benefits would still be of the order of $8,000,000.

Highways and railways suffer from flood damage. During the past 65 years the floods which have occurred, if repeated with conditions as in 1941, would cause losses of about $200,000 to highways and railways. This is an average annual loss of about $3,000, which amount capitalized is approximately $100,000. This is a reasonable estimate of benefits to highways and railways for flood benefits under the Regional Plan with conditions

as in 1941. With improvements in the highway system which will probably be made in the future, flood benefits would be increased.

The large industrial plant of the Ecusta Paper Corporation located on Davidson River would be given complete flood protection under the Regional Plan. The existing levees around this plant do not provide protection against maximum floods, but with the reservoir on Davidson River in combination with the existing levee, complete protection would be provided. Although exact estimates have not been made of the damage that would result to this large industrial plant if overflowed by a major flood, comparison with the damages which result to other industrial plants of comparable size indicates that damages would be of the order of a million dollars. While not all of this sum could be claimed as a benefit under the Regional Plan, nevertheless it is apparent that the benefits from the protection afforded to this large industry would be a substantial amount.

The Regional Plan for flood protection would provide protection to the Asheville and Hendersonville Airport which lies immediately below the Burney Mountain Reservoir on Cane Creek. The Burney Mountain Reservoir is designed so that occasional large floods may overflow the spillway but even during such floods, which come only at long intervals of time, the amount of flooding of the airport would be greatly reduced and would not be serious.

Downstream from Asheville neither the Regional Plan nor the plan for Asheville only would afford complete protection, the degree of protection being less as the distance downstream from Asheville becomes greater. Those floods which originate above Asheville would be materially reduced and substantial benefits would result downstream to the Southern Railway, the town of Marshall, and other properties along the river which have been damaged by floods in the past. It has not been possible within the time available for preparing this report to make a careful analysis and evaluation of these benefits. Based on limited study, it is estimated that these benefits would approximate $400,000.

The following is a recapitulation of the total direct benefits that would result from the Regional Plan.

Asheville including Biltmore	$ 5,000,000
Agricultural Lands (Based on Increased Value of Lands)	3,000,000*
Highways and Railroads above Asheville	100,000
Industries above Asheville	300,000
Other Interests above Asheville including Airport	200,000
All benefits below Asheville	400,000
Total	$ 9,000,000

*Benefits to agricultural lands would be $8,000,000 based on potential benefits.

Asheville Only Plan

The benefits of the Asheville Only Plan would be limited almost entirely to the city of Asheville and highways, railroads, and other property downstream. A flood 5 feet higher than the stage of the flood of 1916 would cause direct physical damages to Asheville estimated to be $5,000,000. Such a loss would include the almost complete destruction of a number of large industrial plants within the city limits and would cause serious depreciation in values within the entire city. Consequently, removal of this flood hazard would be worth more than the direct damage from such a flood. The benefits to areas downstream from the city would be substantially the same as would accrue under the Regional Plan.

Recapitulation of direct benefits under this plan are:

Asheville including Biltmore	$ 5,000,000
All benefits below Asheville	400,000
Total	$ 5,400,000

Power Possibilities

Some thought has been given to the possibility of combining power development with the flood control storage dams proposed above Asheville.

Contrary to the situation which prevails on the Tennessee River, studies show that major floods from the area above Asheville may be expected at any season of the year. Accordingly, the flood control storage provided must be reserved at all times for retention of flood water. It should be emptied within a period of about two weeks after each flood. It cannot be filled at any time for the purpose of generating power.

The volume of storage suggested herein is only sufficient for flood control needs, and this volume is predicated on the assumption that the reservoirs will be maintained completely empty prior to a flood. In other words, these reservoirs are designed purely as detention basins. If impoundage for creation of power head or storage is combined with this plan it would be necessary to build the dams to sufficiently greater height to permit the reservation of the flood control storage on top of that needed for power purposes.

As the upper level of many of the reservoirs has been fixed at elevations as high as practicable on account of the high state of development upstream, which it is sought to preserve, the provision of greater storage would require the dam to be located farther downstream. For instance, the dam proposed for the Britton Mountain site would have to be moved to the more expensive Bent Creek site. Preliminary calculations indicate that the primary power which could be produced at the Bent Creek site would cost in excess of six mills per kilowatt-hour after deducting the cost of the Britton Mountain flood control project and after crediting steam saving value to the secondary power.

The level of the Azalea Reservoir on the Swannanoa River probably could be raised sufficiently to create a power head of at least 70 feet without causing excessive damage upstream or curtailing the flood control storage. However, there is no feasible site downstream for the creation of greater head. The protracted periods of extremely low runoff on this stream are not favorable to power development. All of the smaller reservoirs farther upstream either have their storage limited both by dam site location and development upstream or are located on streams having such low normal flow that power development is either impracticable or appears uneconomical.

In the flood control plan, storage which would inundate large areas upstream from the dam will be so infrequent that cultivation of most of the land in the reservoirs can continue as usual, and only flowage easement need be acquired. With a few exceptions, highways and railroads would not be relocated.

However, if permanent reservoir levels were established for power, there would be much additional expense for relocations, and the permanent flooding of large areas of bottom land would defeat the purpose of the Regional Plan for flood control which seeks to protect land of this character from inundation.

III. ASHEVILLE

The French Broad River flows along the western edge of the city of Asheville separating the city from West Asheville on the opposite side. The main part of the city is located on higher lands of generally rolling topography to the east of the river. Bordering the river on the right bank is a flat flood plain averaging about 1000 feet wide. Plate 8 is a map of the city showing the French Broad River and the limits of flooding during the great flood of July 1916.

The major flood problems of Asheville are primarily concerned with the French Broad water front through the city and with the Biltmore area along the Swannanoa. These two situations will be described separately in the next succeeding sections of this report.

1. FRENCH BROAD WATER FRONT

The Flood Situation

The Flood Plain

Founded in 1796, Asheville has developed since that time into the largest city in western North Carolina. In 1880 the first railroad came through Asheville. The pioneer railroads followed the flood plains along the rivers through the mountains, and the natural location through Asheville was on the flat land bordering the river on the right bank even though these lands are subject to floods. Industries and commercial establishments developed in this same flat area where railroad transportation was readily available. At the present time, the main line of the Southern Railway, the depot and extensive railroad yards together with large industries, warehouses, and business concerns occupy parts of the flood plain. There are opportunities for additional industrial and commercial expansion along the water front provided that the menace of floods is removed.

The River Through Asheville

The natural channel of the French Broad River through the city of Asheville has a bankfull capacity of about 21,000 cubic feet per second, overflowing at a stage of 9 feet on the U. S. Geological Survey gage on Pearson Bridge. In large floods the river overflows its banks, inundating the adjoining lands and damaging the railroad and industrial and commercial concerns. The flood flow in July 1916 was about five times the channel capacity. The flow during the estimated maximum flood would be nearly eight times the channel capacity. From the mouth of the Swannanoa River downstream through the industrial section the fall of the river averages 5-1/2 feet per mile.

Summary of Flood History

Investigations of past floods on the French Broad River at Asheville are summarized as follows:

1. The flood of July 1916 is the largest known to have occurred at Asheville, surpassing all others of record or legend.

2. There is some evidence of a flood approximately equal to that of July 1916 having occurred in April 1791.

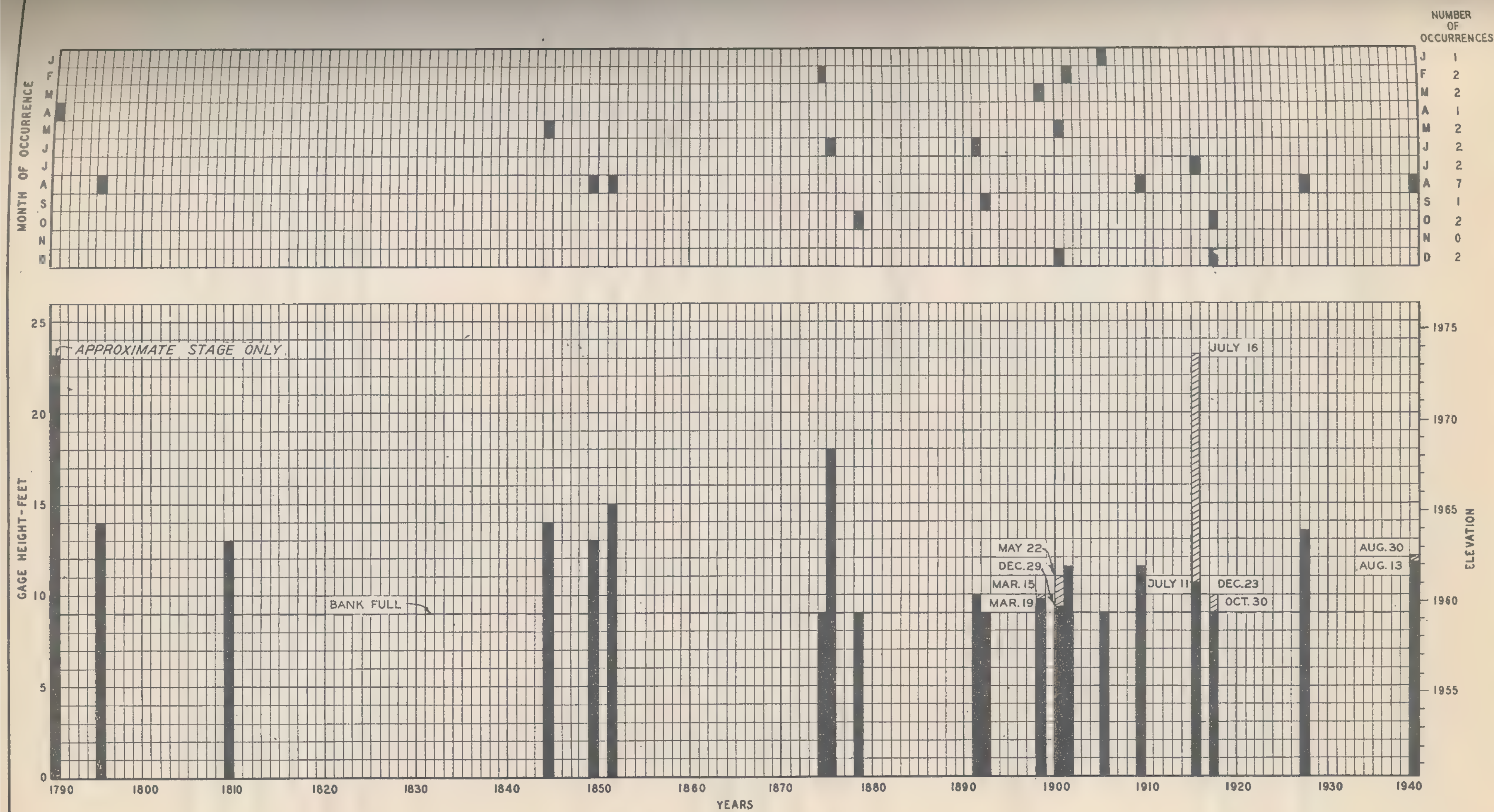
3. Other large floods occurred in June 1876, August 1852, and May 1845.

4. The majority of large floods occur in the summer months as a result of tropical hurricane storms.

5. Large floods cause heavy damages on the Asheville water front; repetition of the 1916 flood would result in tangible losses of about $2,108,000 and of the June 1876 flood of about $1,035,000, exclusive of losses in Biltmore on the Swannanoa River.

6. Encroachments on the flood plain by buildings and other obstructions have reduced the flood carrying capacity of the valley and have caused an increase in flood heights; fills along the bank of the river which crowd the channel of the river are adding to the flood problems.


TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT
AREA FLOODED IN JULY 1916
AT
ASHEVILLE, N. C.
SCALE 0
1 MILE
ASHEVILLE
FRENCH
BROAD
RIVER
SWANNANOA
BEAUCATCHER MOUNTAIN
THE ALDEN CORP.
NATIONAL CASKET CO.
J. M. WESTALL LUMBER CO.
W. H. WESTALL LUMBER CO.
EARL-CHESTERFIELD MILLS
ASHEVILLE COTTON MILL
ASHEVILLE ICE & STORAGE CO.
ASHEVILLE GAS CO.
STANDARD OIL CO.
TEXAS OIL CO.
SOUTHERN RWY. STATION
SOUTHERN RWY. SHOPS
CAROLINA COAL CO.
HILDEBRAND MACHINE CO.
HANS REES TANNERY
GALLIHER BROS. LBR. CO.
BILTMORE FREIGHT YARDS
CITIZENS LBR. CO.
SLAYDEN-FAKES CO.
NATIONAL BISCUIT CO.
COLONIAL DISTRIBUTING CO.
WILLIAMS-BROWNELL CO.
BILTMORE-APPALACHIAN HARDWOOD CO.
ASHEVILLE WAREHOUSE CO.
A & P WAREHOUSE
MC CORMICK FIELD
Lake Kenilworth
Murphy Junction
West Asheville
Emma
Cisco Cove
Piney Mtn
Ross Creek
Haw Creek
Hominy
ASHEVILLE COUNTRY CLUB GOLF COURSE
MUNICIPAL GOLF COURSE
Antioch Ch
Riverview Ch
Mt Olive Ch
VIOLET HILL CEM
GREEN HILLS CEM
Bingham
Moore
Sweeten
RHODODENDRON PARK



TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

FLOODS ABOVE BANKFULL STAGE
FRENCH BROAD RIVER
ASHEVILLE, N. C.
AUGUST 1942

Flood Heights and Occurrences

Plate 9 shows flood heights which have occurred on the French Broad River at Asheville. Table 2 lists the damaging floods which have occurred since 1791. During the early years where information is scant, it is probable that some floods have been missed but it is believed that all major floods are included.

Magnitude of Past Floods

Table 3 gives flood volumes and peak rates of flow together with rainfall data for those large floods for which data are available.

Encroachment on the Flood Plain

Buildings and other improvements in the flood plain of the French Broad River along the Asheville water front obstruct the passage of flood water. There are four highway bridges and one railroad bridge across the river with piers in the channel which obstruct flood flow and afford places for drift to collect. Figure 3 is a picture of the Smith Bridge across the French Broad at Asheville showing heights of large floods. Fills on the flood plain, such as the city of Asheville garbage disposal dump, which crowd out into the river channel restrict the space available for flow. All of these tend to raise the height of floods.

Flood Damages

Table 2 gives estimated damages on the French Broad water front through Asheville for known floods of the past, assuming that these were to recur with improvements as they now exist. In addition to actual flood damages, an item of $784,000 is included which represents depreciation in land values due to the flood hazard. The method of determining this is set forth in Appendix B which also contains other information on damages.

TABLE 2

CREST STAGES OF DAMAGING FLOODS

AND

ESTIMATED FLOOD DAMAGES

WITH DEVELOPMENT AS IN 1941 CAUSED BY REPETITION OF PAST FLOODS

FRENCH BROAD RIVER AT ASHEVILLE, N. C.

Date of Flood			Crest Stage on USGS Gage Gage Height	Elev.	Order of Flood Heights	Total Flood Damage
April		1791*	-			$2,400,000
August		1796	14	1964	4	255,000
		1810	13	1963	7	81,000
May		1845	14	1964	5	255,000
August		1850	13	1963	8	81,000
August		1852	15	1965	3	370,000
February		1875	9	1959	20	13,000
June		1876	18	1968	2	1,035,000
October	17,	1879	9	1959	21	13,000
June		1892	10	1960	15	23,000
September	13,	1893	9	1959	22	13,000
March	15,	1899	10.0	1960.3	16	23,000
March	19,	1899	9.8	1960.1	18	23,000
May	22,	1901	11	1961	13	41,000
December	29,	1901	9.4	1959.7	19	13,000
February	28,	1902	11.6	1961.9	11	50,000
January	23,	1906	8.9	1959.2	24	13,000
August	31,	1901	11.6	1961.9	12	41,000
July	11,	1916	10.7	1961.0	14	23,000
July	16,	1916	23.1	1973.4	1	2,108,000
October	30,	1918	9.0	1959.3	23	13,000
December	23,	1918	10.0	1960.3	17	23,000
August	16,	1928	13.3	1963.6	6	81,000
August	13,	1940	11.7	1962.0	10	41,000
August	30,	1940	12.1	1962.4	9	50,000
		Total -				$7,082,000
		Depreciation in Land Values (See Appendix B)				784,000
		Total Flood Damges - - - - - - - - - - - - - -				$7,866,000

Stages for floods from April 1791 through 1895 are approximations based on a study of historical data and comparison with known conditions during recent floods.

*No definite data are available for this flood but it may have been of the order of that of July 16, 1916.

FIGURE 3 — SMITH BRIDGE, FRENCH BROAD RIVER AT ASHEVILLE

A steel bridge at this site was carried away by the 1916 flood. This flood would reach approximately to the crown of the arches of the center spans on the present bridge. The side arches which are lower than the center arches would obstruct maximum flood flows.

FIGURE 5 — SOUTHERN RAILWAY CRIPPLED BY FLOOD IN 1916

The large yards and roundhouse of the Southern Railway were flooded. Building in foreground is foundry of Carolina Machinery Company. White building in left background is passenger depot. (Southern Railway photo)

FIGURE 6 — RAILROAD EQUIPMENT DAMAGED IN 1916

View from Southern Railway roundhouse at height of flood. Damages to railroad track and equipment were large. (Southern Railway photo)

TABLE 4 (CONTINUED)

SUMMARY OF DAMAGES

FRENCH BROAD RIVER AT ASHEVILLE

Flood of July 16, 1916

Utilities			
Asheville Power and Light Company			
Gas plant	$21,000		
Avery Street Substation	12,750		
Street Railway System	21,000	54,750	
North Carolina Electric Power Co.			
Elk Mountain Steam Plant	24,300		
Elk Mountain Hydro Plant	7,150	31,450	
Southern Bell Telephone and Telegraph Company		3,400	89,600
Agricultural			
30 Acres corn and gardens			1,200
Total			$1,939,000

Damages from Flood of August 1928

This flood, although nearly 12 feet lower than that of July 1916, caused losses of about $123,000. Industrial damage was nearly half of the total. A number of large industries which were damaged severely in 1916 were no longer in business in 1928. The Asheville water front area also did not have the influx of new industries as did the Biltmore section along the Swannanoa basin since 1916. The following is a summary of the estimated damages during this flood.

Industrial	$105,500
Commercial	3,300
Domestic	100
Municipal	2,000
Highways	500
Railroads	10,000
Utilities	1,100
Agricultural	700
Total	$123,200

Damages from Flood of August 11-14, 1940

The damages from this flood on the Asheville water front as shown in the following classified summary were relatively small, totaling only $41,300. The greatest damages suffered in the French Broad region from this flood occurred for the most part on the smaller watersheds where the flood was most intense.

Industrial	$ 29,200
Commercial	1,150
Domestic	100
Municipal	1,100
Highways	200
Railroads	9,000
Utilities	200
Agricultural	350
Total	$41,300

Damages from Flood of August 29-30, 1940

This flood was slightly more than half a foot higher on the Asheville water front than the mid-August flood. Damages, summarized in the following tabulation, were less as losses from the first flood had not yet been replaced or repaired.

Industrial	$ 16,600
Commercial	2,200
Domestic	100
Municipal	2,600
Highways	200
Railroads	6,000
Utilities	900
Total	$28,600

Flood Protection Plans for Asheville

Consideration has been given to the protection of the industrialized French Broad River water front through the city of Asheville against

FIGURE 7 — U. S. HIGHWAY 70 OVERFLOWED BY SWANNANOA RIVER AUGUST 13, 1940

700 feet of the highway were overflowed and washed out by undercutting.

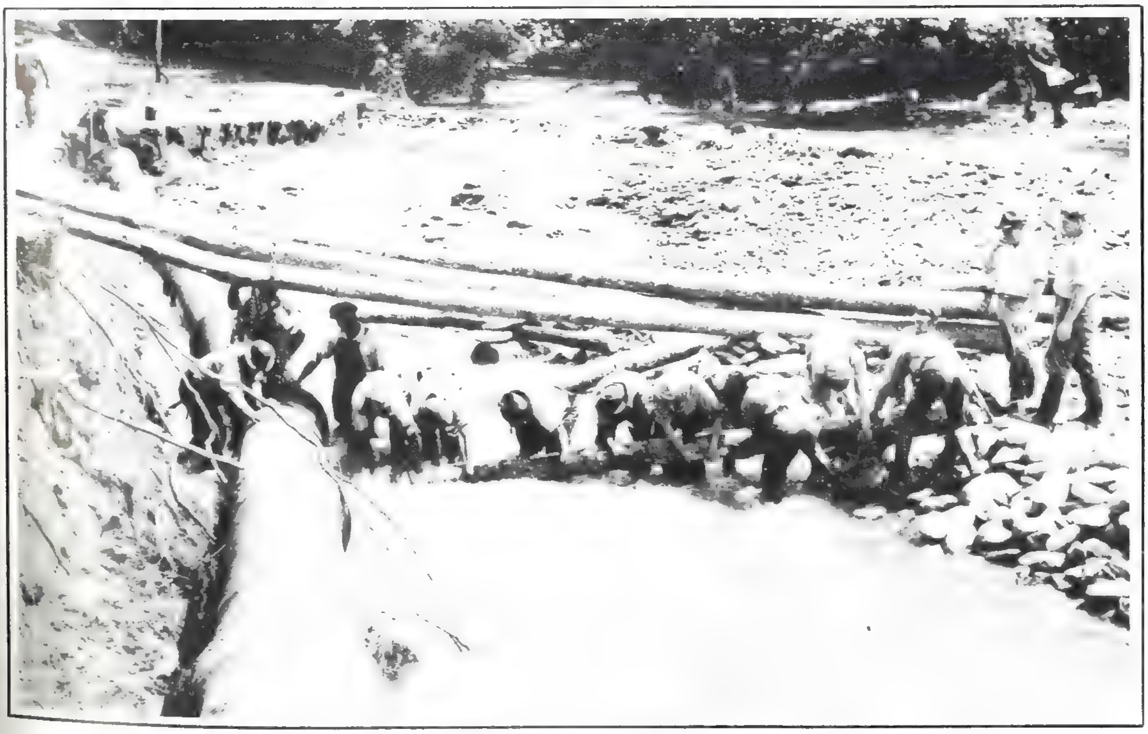


FIGURE 8 — ASHEVILLE WATER LINE BROKEN BY WASHOUT, AUGUST 1940

Beetree Creek cut into the bank causing a break in the main water line to the city of Asheville. The picture shows repairs being made after the flood had receded. (Asheville Citizen-Times photo)

floods by storage reservoirs upstream from Asheville, by levees along the water front which would not be overtopped by maximum floods, by enlargement of the present river channel to a size sufficient to carry the maximum floods below banks, and by combinations of these methods.

Study of the situation has developed that none of these methods are feasible by themselves. There is insufficient room through the congested river front area to construct levees of the height which would be necessary without reduction of flow by reservoirs. Such levees in any event would have to be very high and would be costly. Enlargement of the river channel is also impractical due to the limited possibilities for enlargement and disposal of material and the high cost of such a plan. Reservoirs offer the best possibility for control by single means but to use this method alone would require large storage space upstream from Asheville with consequent flooding of valuable urban and rural property which would make the cost prohibitive. As a result of the investigations of the various possibilities, it appears that the most feasible method is a combination of upstream reservoirs and a levee of moderate height along the right bank of the river through the city.

As previously set forth, two plans including storage reservoirs and a levee have been developed, each of which provides complete flood protection for Asheville. The first is the comprehensive Regional Plan for flood protection and the second gives protection only to Asheville and down river points.

Asheville Flood Protection As a Part of Regional Flood Protection

This plan shown on plate 4 has been previously described. It includes principally seven storage reservoirs and a levee along the Asheville water front of the French Broad River. The reservoirs included in this plan are each described under the respective sections of this report which relate to the particular streams on which they are located.

Levee Along French Broad River--Beginning near the Southern Railway bridge crossing, the levee extends upstream along the right bank of the river to the Swannanoa River, then continues upstream along the Swannanoa to about a quarter of a mile southeast of the Southern Railway roundhouse where natural ground is as high as the top of the levee. Plate 10 shows the location and general details of the proposed levee. Plate 11 is a profile showing the height and other dimensions of the levee.

The grade line of the levee provides a margin of 2 feet above the water surface for the outflow from the upstream reservoirs plus the runoff from the uncontrolled area below the dams during the greatest possible future flood.

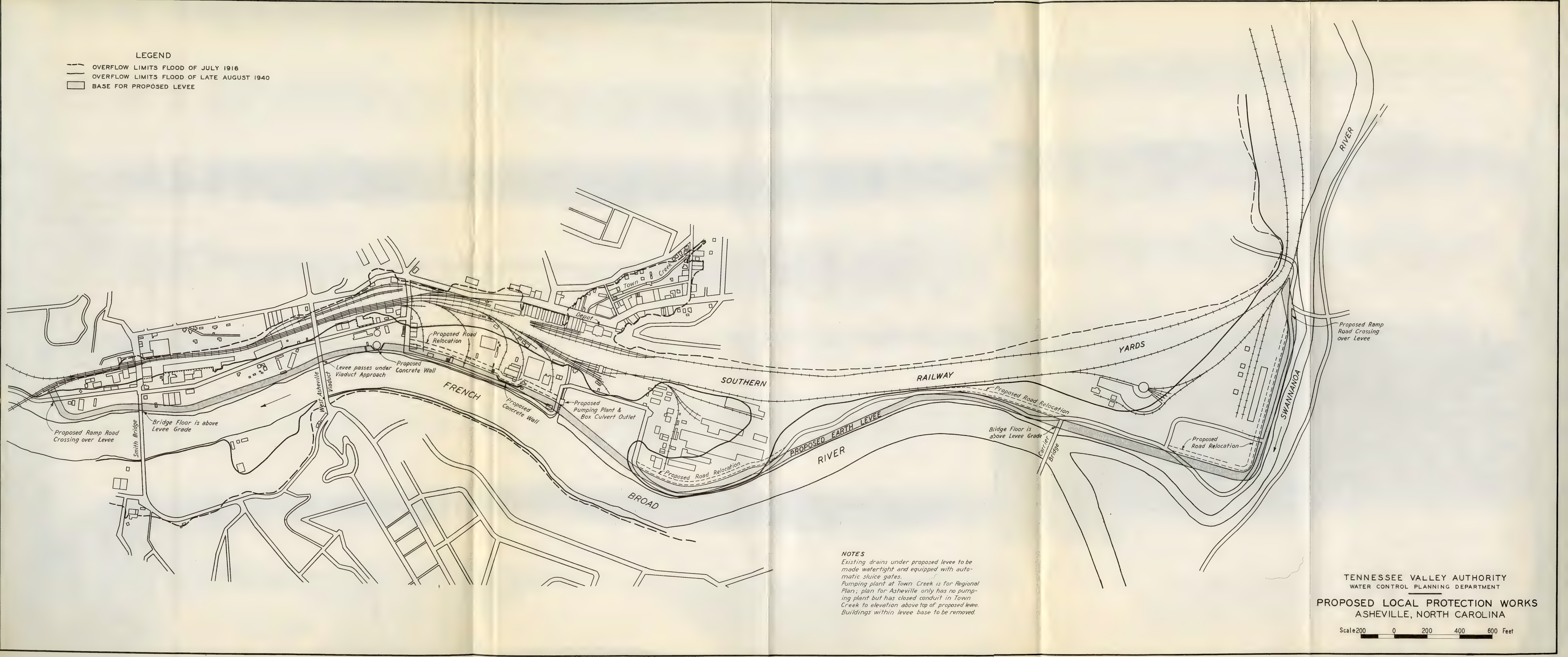
The Riverside Drive roadway would have to be relocated in some places. Such relocations are shown on plate 10. In order to allow room for the roadway on the land side of the levee at the Baker Packing Company's plant and at one of the large tanks at the gas plant, two short sections of concrete wall would be required.

Existing sewers and drains would be reconstructed as necessary and automatic sluice gates or valves would be placed on these to prevent flood water backing up into the protected area after the levee is constructed. For Town Creek, which drains a watershed of 1075 acres in the vicinity of the Southern Railway depot, a large box culvert and pumping plant would be provided where the creek crosses under the levee so that storm runoff could be pumped into the river during high flood stages. This is necessary to prevent flooding of property behind the levee by water running off from the Town Creek watershed.

The levee would be built of earth obtained from borrow pits on the west side of the river.

Asheville Only Flood Protection

This plan, shown on plate 5 and previously described, includes the Azalea Reservoir on Swannanoa River, Britton Mountain Reservoir on the French


LEGEND
OVERFLOW LIMITS FLOOD OF JULY 1916
OVERFLOW LIMITS FLOOD OF LATE AUGUST 1940
BASE FOR PROPOSED LEVEE
Town Creek
Depot
Proposed Road Relocation
Proposed Concrete Wall
Levee passes under Viaduct Approach
West Asheville Viaduct
Smith Bridge
Bridge Floor is above Levee Grade
Proposed Ramp Road Crossing over Levee
FRENCH
Proposed Concrete Wall
Proposed Pumping Plant & Box Culvert Outlet
SOUTHERN
RAILWAY
YARDS
PROPOSED EARTH LEVEE
Proposed Road Relocation
RIVER
BROAD
Bridge Floor is above Levee Grade
Carrier Bridge
Proposed Road Relocation
Proposed Road Relocation
SWANNANOA
RIVER
Proposed Ramp Road Crossing over Levee
NOTES
Existing drains under proposed levee to be made watertight and equipped with automatic sluice gates.
Pumping plant at Town Creek is for Regional Plan; plan for Asheville only has no pumping plant but has closed conduit in Town Creek to elevation above top of proposed levee.
Buildings within levee base to be removed.
TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT
PROPOSED LOCAL PROTECTION WORKS
ASHEVILLE, NORTH CAROLINA
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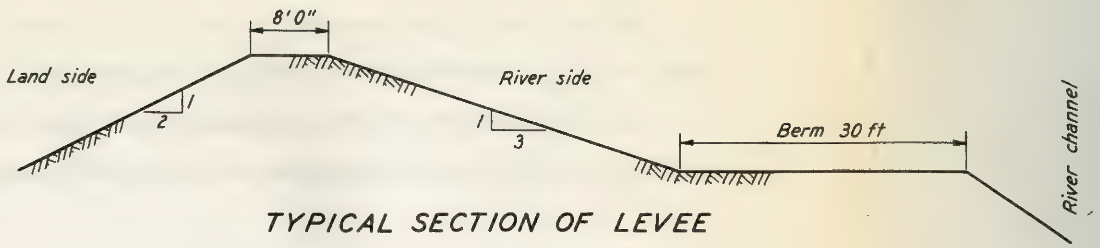

TYPICAL SECTION OF LEVEE

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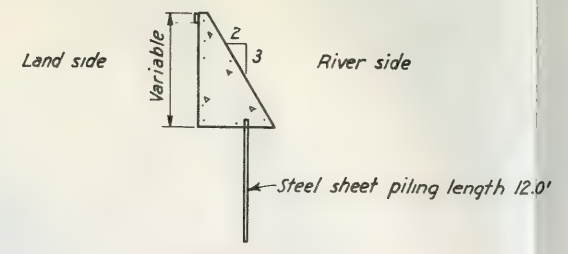

TYPICAL
CONCRETE WALL SECTION

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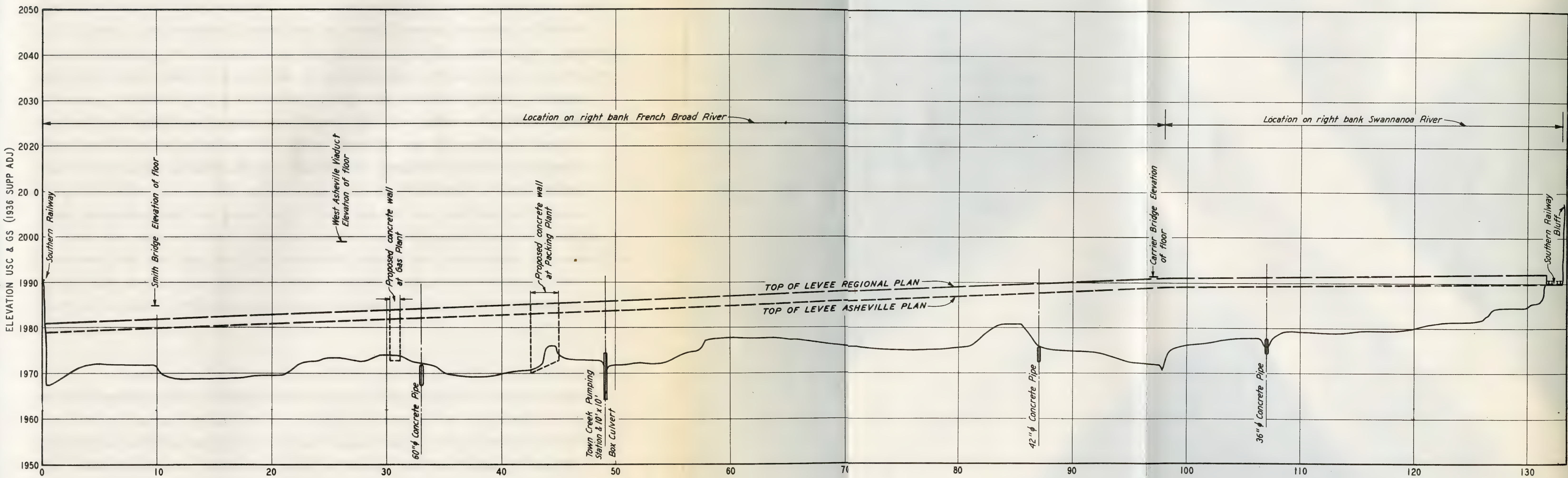


TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

PROFILE
OF
PROPOSED LEVEE
ASHEVILLE, NORTH CAROLINA

Broad River just upstream from Asheville, and a levee along the French Broad River through Asheville. The Azalea Reservoir on Swannanoa River is described in the section of this report relating to that stream. The Britton Mountain Reservoir is described in the next section of this report.

Britton Mountain Reservoir--The dam to create this storage reservoir is located in a narrow section of the French Broad River Valley where the banks are generally steep and the bottoms along the river quite narrow. Plate 12 is a general plan showing the location and other details of Britton Mountain dam. The dam would be a concrete structure with a maximum height of 70 feet. The reservoir above the dam would have a capacity to store runoff amounting to 6 inches from the watershed of 664 square miles upstream with the water level at the crest of the spillway, 15 feet below the top of the dam. Concrete outlet conduits through the dam would have a combined capacity of 40,000 cubic feet per second with the water at spillway level. There would be no gates on the outlet conduits and the reservoir would operate entirely automatically. The outlet conduits are purposely made large in order to avoid as much as possible the flooding of agricultural lands upstream from the reservoir. The conduit size has been determined so that the outflow from Britton Mountain Reservoir plus that from Azalea Reservoir and the uncontrolled watershed between the reservoirs and Asheville would flow through the Asheville water front reach of the French Broad River at a level affording a safe margin below the top of the proposed levee.

There are no railroad lines within the reservoir area. Highways in the reservoir will be affected for only a few days at a time at comparatively long intervals and the expense of removal or adjustment is not justified. Neither would this be desirable since it is contemplated that the lands within the reservoir would be farmed and the highways should remain in order to provide access to the lands.

The geology of the Britton Mountain site (Appendix D) indicates that this is one of the least desirable sites in the region. At this site there is a thick overburden of earth and unsound rock, especially in the

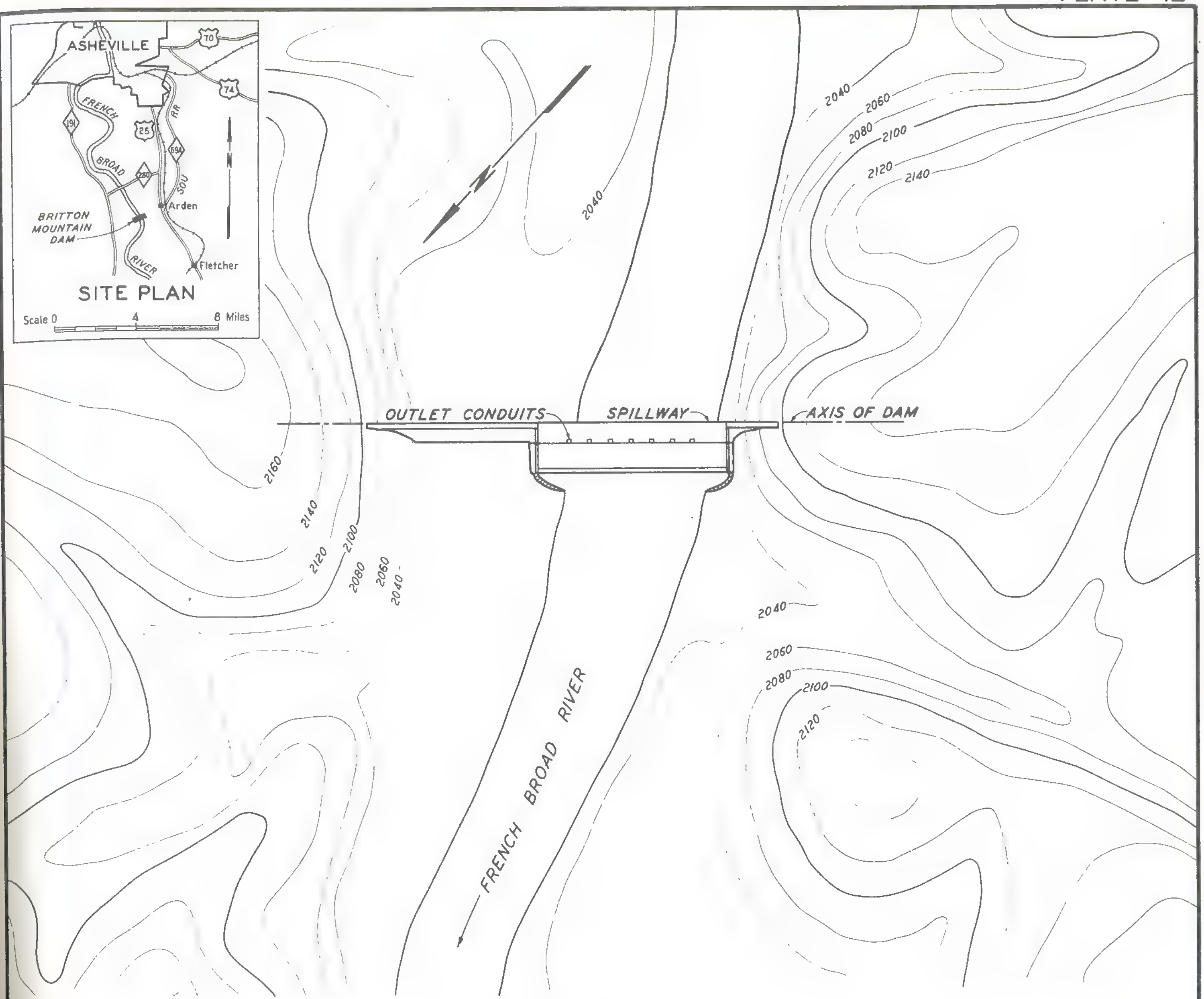
abutment areas, the extent of which could only be determined by core drilling. In the opinion of the Authority's Chief Geologist deep excavation and extensive grouting would probably be required to insure a safe dam at this location which would tend to increase costs.

Levee Along French Broad River--The levee along the French Broad River under this plan would follow the general location of that shown on plate 10, being the same as that for the Regional Plan. The height of the levee, however, would be 2 feet lower as shown on plate 11. As in the case of the Regional Plan, the height of the levee has been reduced one foot because of the anticipated benefits which will result from the improvement in land cover contemplated to be made on the watershed upstream from Asheville.

Adjustments in the Riverside Drive roadway and in existing sewers and drains would be similar to those under the Regional Plan. Town Creek storm runoff when the French Broad is in flood would be discharged into the river through a closed concrete drain which would extend up the creek to an elevation above high water in the river.

Woodfin Section of Asheville

Downstream from the Southern Railway bridge crossing of the French Broad River there are some industries and commercial establishments on the right bank in the Woodfin section of Asheville. These industries will be benefited by the reduction in flood heights from the upstream reservoirs under either the Regional Plan or the Asheville Only Plan, but, in addition, complete protection against large floods would require a levee along the river. At the present time, the development there is not sufficient to justify the cost of a levee. It might be that at some future time the pressure for additional lands for industrial development might make it worth while to give levee protection to this area after the upstream reservoirs have been constructed.



PLAN

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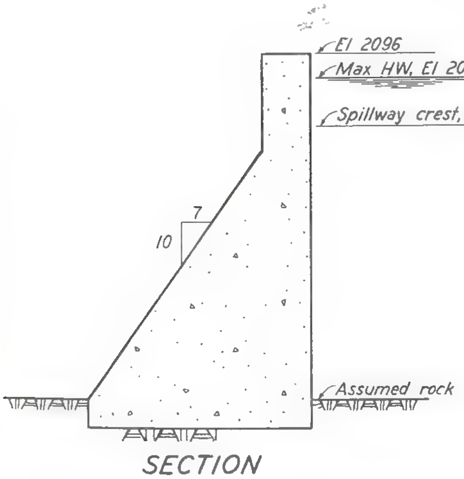


SECTION

Scale 0 20 40 Feet

NOTES:

Design shown is preliminary and subject to change when more detailed information on the site and materials available for construction is obtained prior to construction.

Site topography taken from advance sheets of USGS-TVA topographic maps.

Low water at elevation 2026. Maximum height of dam, 70 feet.

460-foot wide ogee spillway section.

Seven outlet conduits through spillway section, uncontrolled.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

GENERAL PLAN
BRITTON MOUNTAIN DAM
FRENCH BROAD RIVER

2. BILTMORE AND SWANNANOA RIVER

The Flood Situation

In addition to the water front on the French Broad River, flood protection for Asheville must include control of floods on the Swannanoa River which flows through the highly developed industrial and commercial property in Biltmore. Regardless of floods on the remainder of the French Broad watershed, this part of Asheville is subject to devastating floods from the Swannanoa itself so that complete control of the Swannanoa is necessary.

The Swannanoa River drains a rugged mountainous watershed of 133 square miles immediately east of the city of Asheville. The Craggy Mountains on the northeast border of the watershed reach elevations of over 6000 feet while in the river valley through the Biltmore section of Asheville elevations are only 2000 feet. Plate 13 is a map of the basin showing the principal features and the proposed Azalea Reservoir.

The Swannanoa Valley was one of the main routes by which pioneer settlers from the east crossed the mountains through Swannanoa Gap and came into western North Carolina and Tennessee. Settlement in the valley began in the early 1780's. The first railroad from the east was completed down the Swannanoa Valley to Biltmore in 1880.

Highways and industries followed the railroad and located on the flat lands along the river. Development of the valley has continued through the years, and at the present time in the Biltmore section of Asheville and upstream from Biltmore to Azalea are many important industrial and commercial establishments in the flood plain of the river. The river valley lands from Biltmore to Azalea are attractive for further industrial and commercial expansion which has not taken place because of the hazard of large floods.

The main line of the Southern Railway east from Asheville extends generally up the valley of the Swannanoa River. Main arterial highway U. S. 70 parallels the railroad through the valley.

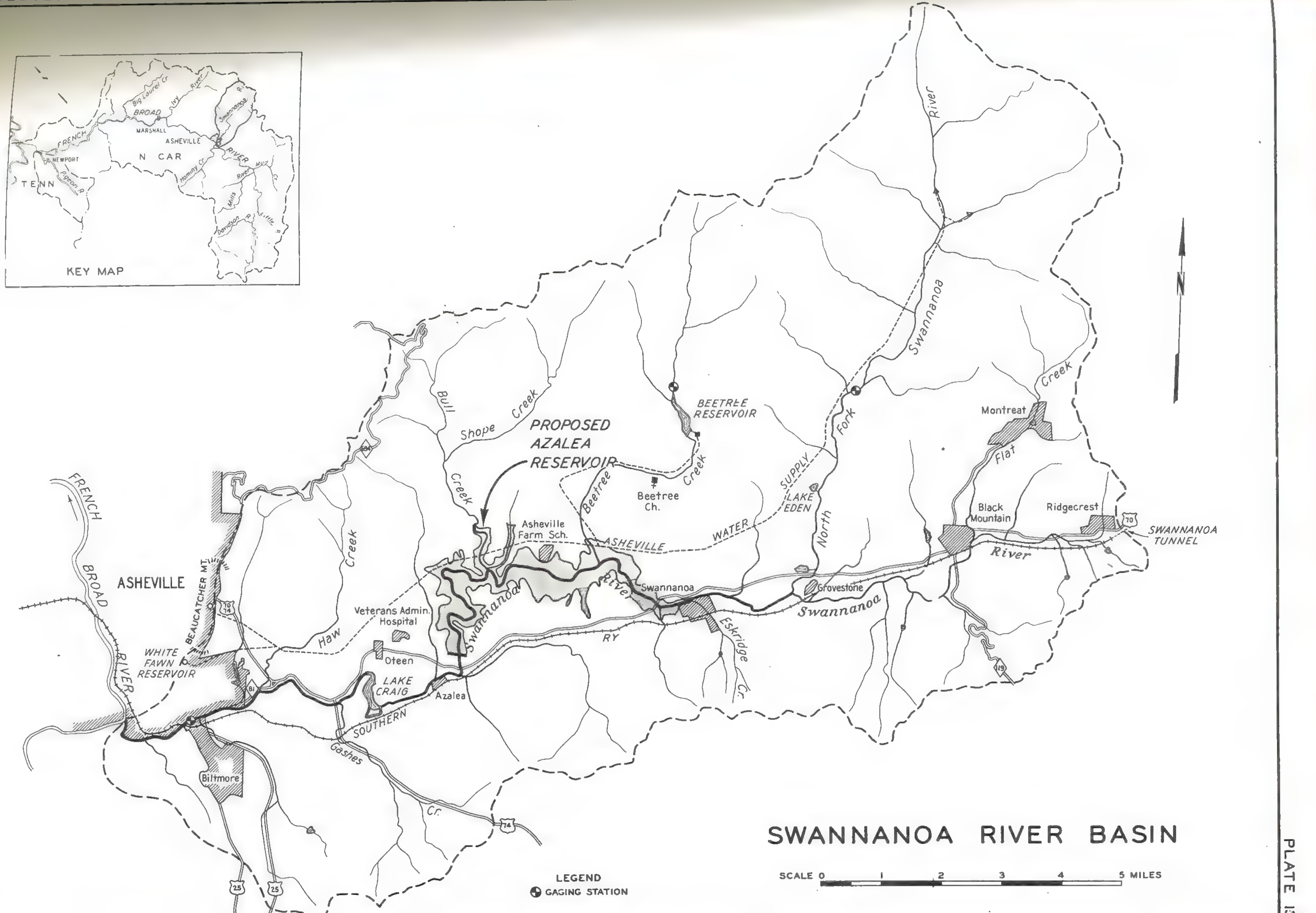
The city of Asheville derives its water supply from a small storage reservoir on Beetree Creek and from intakes on the North Fork of the Swannanoa. Industrial water supplies are taken directly from the river. The best agricultural lands in the basin are the bottom lands along the river.

The River and Its Valley

The Swannanoa is a mountain stream, fed for the most part by tributaries to the north of the main river with only a few small creeks entering from the south. The principal tributaries, Bull Creek, Beetree Creek, and the North Fork, head in steep wooded mountain slopes from which heavy runoff results during intense storms. A large part of the Beetree Creek and North Fork watersheds are owned by the city of Asheville for water supply purposes. Swannanoa River floods are important in causing floods on the French Broad River at Asheville.

At the Biltmore stream gaging station, the drainage area is 130 square miles, bankfull stage is 12 feet, and the capacity of the river channel at that stage is 6200 cubic feet per second. The flood flow in August 1940 was more than three times and in July 1916 about four times the channel capacity.

From the mouth of the river upstream through the Biltmore industrial section to Mile 5, the fall of the river averages 9 feet per mile. From Mile 5 to Mile 7 at Azalea, the slope is 12.5 feet per mile. Through this reach the bottoms subject to overflow along the river are narrow. From Azalea to above the mouth of Bull Creek at Mile 11, the river flows through a rocky steep-walled gorge with a slope of 13 feet per mile. Above Mile 11, the valley widens out with good bottom farming lands along the river for the next three miles upstream. From the town of Swannanoa at Mile 15.5 to the mouth of North Fork at Mile 17.4, the slope of the



SWANNANOA RIVER BASIN

river becomes much steeper, being about 28 feet per mile. The bottom lands through this upper reach are largely gravel and rock and overflow damage is largely to roads and bridges.

Summary of Flood History

Results of investigations of past floods in the Swannanoa Basin are summarized as follows:

1. The dates and gage heights at Biltmore of the five largest floods which are known to have occurred on the Swannanoa River in the past 150 years are:

Date	Gage Height Feet	
April 1791	26	(Approximate)
July 1916	20.7	
Aug. 1940	18.95	
Aug. 1928	18.7	
May 1845	18	(Approximate)

2. Reasonable evidence from independent sources indicates that the maximum flood of which there is knowledge occurred in April 1791 and was about 5 feet higher than the more recent great flood of July 1916.

3. It is estimated that floods above a bankfull stage of 12 feet at Biltmore occur on the average of about one every 9 or 10 years; not infrequently two floods occur in the same year.

4. The flood records of the past 50 years indicate that the Swannanoa River is subject to large floods periodically; during the interim between large floods, no floods have occurred.

5. The monthly distribution of known floods above bankfull stage during the past 150 years is as follows:

February	- 1	July	- 1
April	- 1	August	- 5
May	- 2	December	- 2
June	- 1		

6. No floods are known to have occurred in the months of January, March, September, October, and November.

7. Although the majority of the largest floods on the Swannanoa River occurred in the summer months as a result of tropical hurricane storms, the highest flood on the river came in April, probably from a different type of storm.

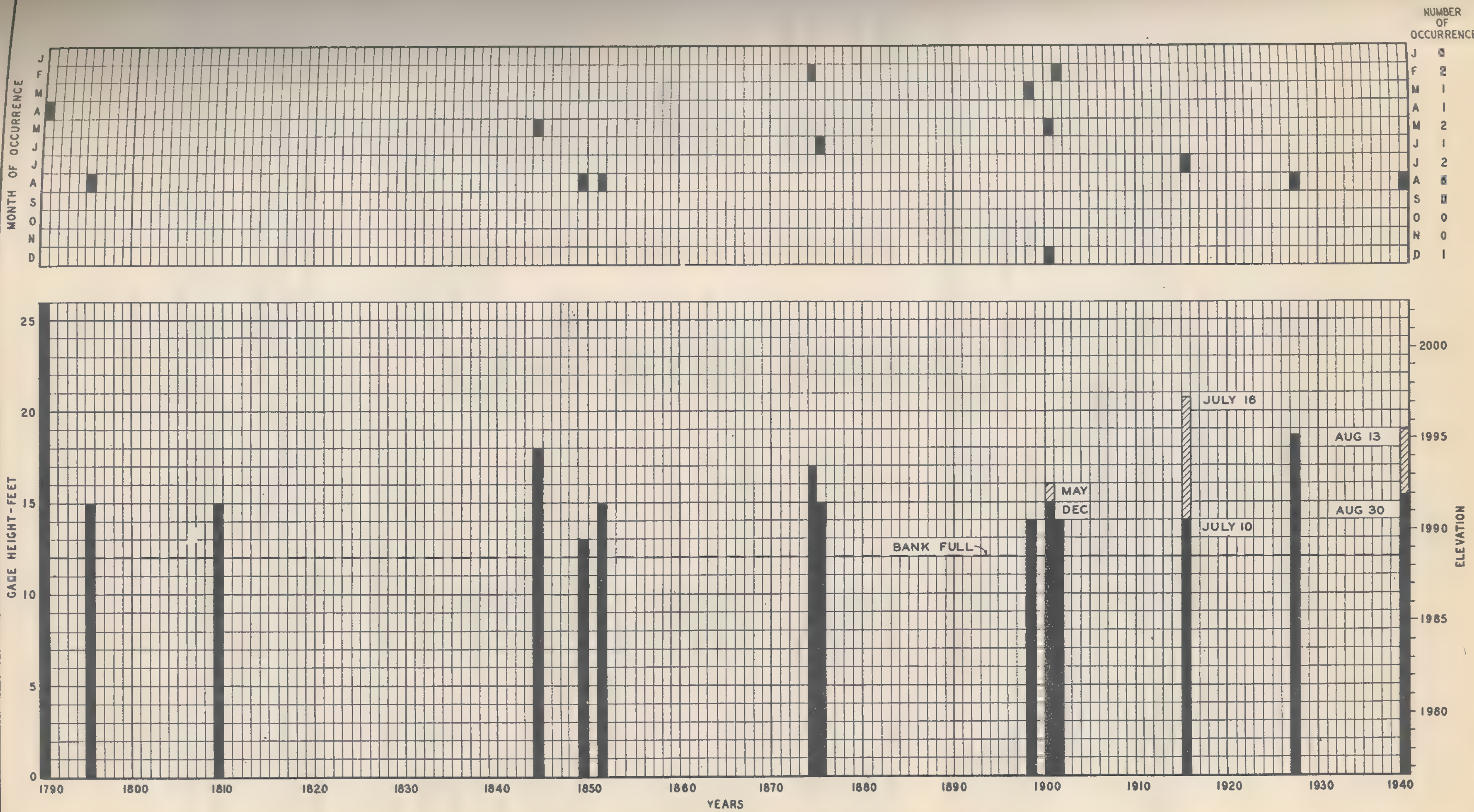
8. Buildings constructed within the flood plain of the river through Biltmore since 1916 have reduced the flood carrying capacity of the valley and have caused an increase in flood heights.

9. Bridges on the Swannanoa obstruct flood flow and cause heading up of the water; the profiles of the 1940 floods show a heading up of 4 feet through the Southern Railway bridge and two highway bridges in Biltmore.

Flood Heights and Occurrences

Plate 14 shows flood heights which have been experienced at the site of the present Biltmore stream gaging station 1-1/2 miles upstream from the confluence of the Swannanoa with the French Broad. Table 5 lists the damaging floods which have occurred since 1791. Although flood information during the early years is meager, it is believed that the large floods which have occurred within the period of 150 years covered by the investigation have been discovered. It seems probable that in the years prior to 1890 there were small floods on which no information of any kind now exists either in any recorded form or in the memory of man. Such floods would have caused little or no damages in those pioneer periods but would be more serious under present development conditions.

Examination of the flood heights for the past 50 years for which there is fairly definite flood information, either from stream flow records, newspapers or other sources shows that, for this period, the flood years on the Swannanoa are separated, on the average, by about 10 years during which intervals the stream lacked three or four feet of even approaching bankfull stages. The situation is analogous to a volcano which is quiescent for years and then erupts violently, repeating this cycle through the ages. If this half century is representative of the flood history of the stream, then the Swannanoa is a river which is characterized by large floods occurring on the average once in a decade with no floods, even of moderate heights, occurring in between. The period of record is too short to draw



TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

FLOODS ABOVE BANKFULL STAGE
SWANNANOA RIVER
BILTMORE, N.C. STREAM GAGE SITE
AUGUST 1942

TABLE 5

CREST STAGES OF DAMAGING FLOODS

AND

ESTIMATED FLOOD DAMAGES

WITH DEVELOPMENT AS IN 1941 CAUSED BY REPETITION OF PAST FLOODS

SWANNANOA RIVER

Date of Flood		Gage Height at Biltmore Feet	Elevation Above Sea Level Feet	Order of Flood Peaks	Total Flood Damage	Damages Below Proposed Dam Site
April	1791	26	2003	1	$1,500,000	$1,150,000
August	1796	15	1992	9	52,000	45,000
	1810	15	1992	10	52,000	45,000
May	1845	18	1995	5	206,000	141,000
August	1850	13	1990	17	14,000	11,200
August	1852	15	1992	11	52,000	45,000
February	1875	17	1994	6	130,000	100,000
June 17,	1876	15	1992	12	52,000	45,000
Mar. 19,	1899	14	1991	14	18,000	15,000
May 21,	1901	16	1993	7	88,000	77,000
Dec. 30,	1901	15	1992	13	52,000	45,000
Feb. 28,	1902	14	1991	15	18,000	15,000
July 10,	1916	14	1991	16	18,000	15,000
July 16,	1916	21	1997.6	2	1,230,000	941,000
Aug. 16,	1928	18.7	1995.3	4	206,000	141,000
Aug. 13,	1940	18.95	1995.5	3	290,000	185,000
Aug. 30,	1940	15.30	1991.9	8	28,000	19,000
Land and Property Devaluation					634,000	634,000
Total -					$4,640,000	$3,669,200

Stages for floods from April 1791 to July 10, 1916, are approximations to the nearest foot in elevation based on a study of historical data and comparison with known conditions during recent floods.

Stages for the July 16, 1916, and August 16, 1928, floods are from high water marks. The two August 1940 flood stages are from recording stream gage records.

any such definite conclusion, but the meteorology of this region tends to support the theory of large floods or none for the Swannanoa River.

Experience during the past 50 years shows that two floods have occurred in the same years on three occasions. In 1916 and 1940 these floods came so close together that damages from the two were but little greater than for one flood. The floods of December 30, 1901, and February 28, 1902, were only two months apart.

Magnitude of Past Floods

Table 6 gives flood volumes and peak rates of flow for floods for which this is available.

TABLE 6

FLOOD FLOW AND RUNOFF

SWANNANOA RIVER AT BILTMORE

(Drainage Area 130 Square Miles)

Date	Average Rainfall Inches	Gage Height Feet	Peak Discharge Amount c.f.s.	Peak Discharge Per Sq.Mi. c.f.s.	Surface Runoff Ac.Ft.	Surface Runoff In.	Runoff to Rainfall Percent
July 1916	7.7	21[a]	23,000[+]	177	24,800	3.6	46
August 1928	-	18.7	17,800	137	-	-	-
Aug. 13, 1940	9.4	18.95	18,400	142	22,800	3.3	35
Aug. 30, 1940	7.6	15.30	11,200	86	15,100	2.2	29

[a] Stage affected by backwater from French Broad.

[+] Estimated from best available data.

Encroachment on Flood Plain

At the time of the July 1916 flood the industrial and commercial development of the Biltmore area within the flood plain of the Swannanoa River had a good start. However, the main boom in building in

FIGURE 9 — SOUTHERN RAILWAY BRIDGE ACROSS SWANNANOA RIVER IN BILTMORE

This is one of 12 bridges below the proposed Azalea Dam site, nearly all of which offer serious obstruction to large floods.

this area came after 1916 and before 1928, during which time a considerable number of additional buildings were constructed within the area subject to flooding along the Swannanoa. These buildings occupy space which formerly was overflow flood channel, reduce the carrying capacity of the valley and increase flood heights over what they otherwise would be.

Some fills have been and are still being made into the natural channel of the river which constrict the channel and reduce its carrying capacity. This increases the likelihood of small floods overflowing the banks of the river.

Between the mouth of the Swannanoa and Azalea there are 11 bridges across the river. Most of these are lower than the large floods and obstruct the flood flow, causing a heading up of water above the structures. Figure 9 shows one of these bridges together with the elevations for major floods. Flood control by a detention reservoir upstream from Azalea would so reduce the volume of flow in the Swannanoa River that the present bridges would not offer serious obstruction to any flows which will occur in the Swannanoa River after the reservoir is constructed.

Flood Damages

Table 5 gives estimated flood damages on the Swannanoa River for known floods of the past, assuming that these were to recur with improvements as they now exist. Damages are estimated for the stream as a whole and for the reach downstream from the proposed Azalea Dam. In addition to actual flood damages, an item of $634,000 is included for land and property devaluation as a result of the flood hazard. The method of determining this is described in Appendix B, which also contains other information on damages.

Damages from Flood of July 16, 1916

This flood caused damages exceeding those of any other flood. A repetition of this flood under present development conditions is estimated would cause damages about double those which actually occured in 1916.

Industries in the reach from Azalea to Biltmore suffered particularly heavy damages from this flood. Damage consisted of destruction of buildings and equipment, silting of machinery and stock, and loss of lumber stock.

Commercial damage was confined largely to Biltmore. This community, now a part of Asheville, was developed as a model village by the late George Vanderbilt whose estate adjoins it on the west. The estate owned the commercial area around the Plaza and developments in this location were practically wiped out by the flood. The Vanderbilt estate also suffered the heaviest domestic damages as 20 of the 56 houses in the village were badly flooded.

Damages to highways and bridges within the area were large.

On the Asheville-Salisbury line of the Southern Railway, which extends up the Swannanoa Valley, the track was washed away in many places so as to be impassable. In some locations the roadbed was lost. Bridges and trestles were washed out or severely damaged.

Agricultural losses were tempered by the fact that the utilization of the Swannanoa Valley for other purposes limits the agricultural development along this stream. The largest single loss was to the nursery and greenhouses on the Vanderbilt estate located on the flood plain at the present site of the Biltmore freight yard of the Southern Railway.

The following is a summary of the estimated damages which occurred during the flood of July 1916 classified according to type of damages.

Industrial - - - - - - - - - - - - - -	$144,000
Commercial - - - - - - - - - - - - - -	11,000
Domestic - - - - - - - - - - - - - -	31,000
Municipal - - - - - - - - - - - - - -	5,000
Highways - - - - - - - - - - - - - -	84,000
Railroads - - - - - - - - - - - - - -	290,000
Utilities - - - - - - - - - - - - - -	1,200
Agricultural - - - - - - - - - - - - - -	80,000
Total	$646,200

Damages from Flood of August 1928

Although the 1928 flood was not as severe as either the 1916 or 1940 floods, considerable damages resulted. When the flood occurred, the area had just passed through a period of expansion during which land values had risen and an extensive building program had been carried out. By this time much of the Biltmore lands had been divided into small individual holdings, and numerous new industries and commercial developments were locating on the flood plain along the Swannanoa.

The following is a summary of the estimated damages which occurred during the flood of August 1928 classified according to type of damages.

Industrial	$121,200
Commercial	4,800
Domestic	3,100
Municipal	5,900
Highways	14,000
Railroads	6,000
Utilities	600
Agricultural	10,000
Total	$165,600

Damages from Flood of August 11-14, 1940

Heavy damages were suffered from this flood particularly by industries in the Swannanoa basin. After the 1928 flood a number of new firms located in the Biltmore section. This influx of new business and development of the area resulted in increased damages beyond those attributable to the increased flood height. In the extensively developed area along the reach from Azalea to Biltmore, 30 industries and 43 commercial establishments were damaged. Plate 15 shows the area overflowed by the August 1940 floods and the location of properties and concerns which suffered large damages. According to the Asheville Real Estate Board (Appendix B), recurring floods have damaged these industries to such an extent that it has now resulted in devaluation of the land in this area.

Damages to industries from this flood amounted to almost $180,000, which is 60 percent of the total damage. This occurred to 30 industries located in the Azalea to Biltmore section of the river. Commercial damages were suffered by service stations, grocery stores, restaurants, drug stores, hardware stores, and miscellaneous commercial establishments in the vicinity of Biltmore Plaza. Domestic damages resulted when flood waters in Biltmore entered 26 houses and surrounded eleven others. The city of Asheville's 24-inch cast iron water supply line from the Beetree Reservoir and the intake lines on the North Fork of the Swannanoa were washed out in places. Agricultural crops on the valley lands were lost.

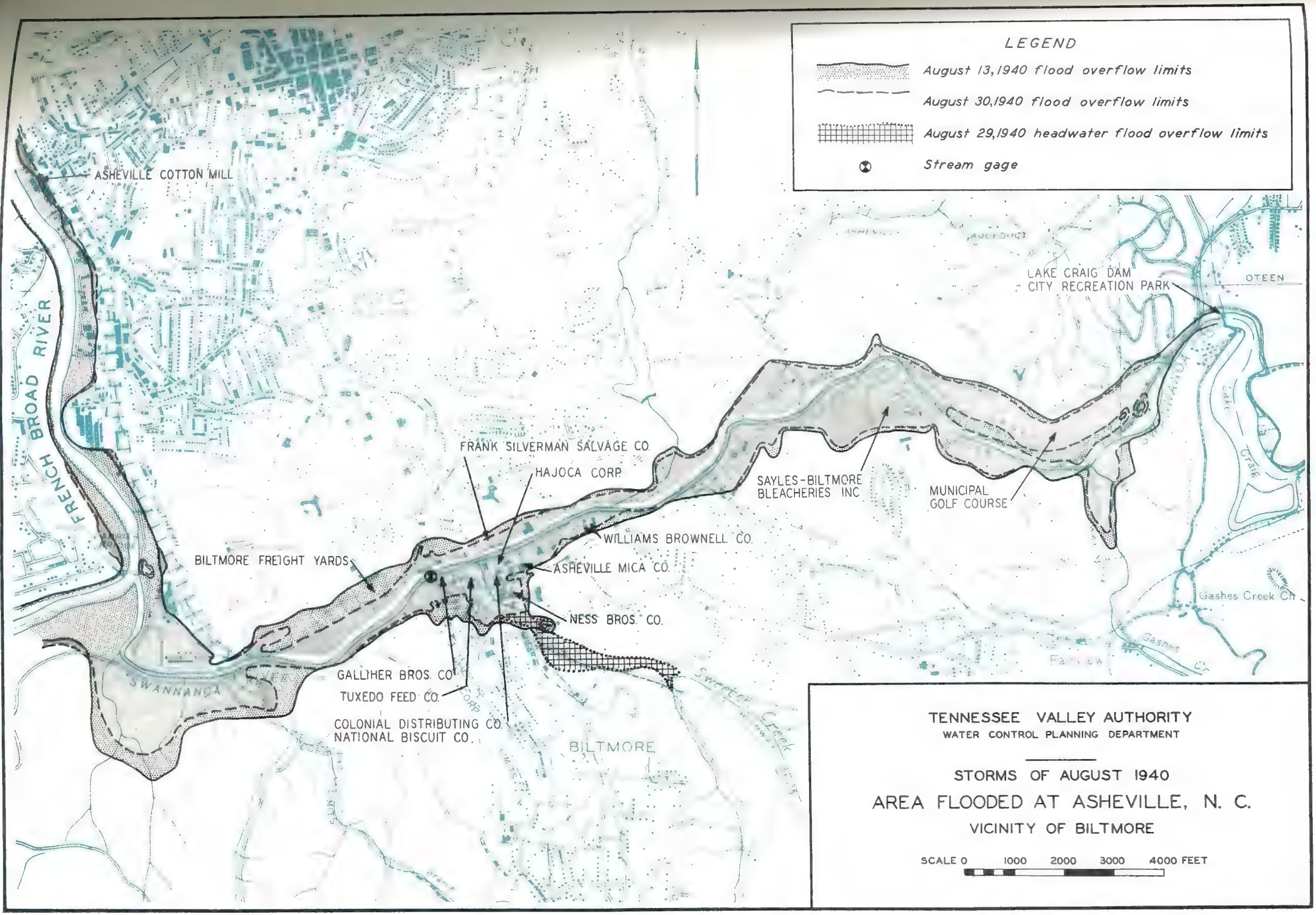
U. S. Highway 70 was damaged in a number of places in the Swannanoa Valley and county roads were badly washed. Several bridges were damaged. The Southern Railway had 1000 feet of track washed out near Grovestone and in the Biltmore freight yards water flowed from 1 to 2 feet over the tracks, washing out ballast and disrupting alignment of track.

The following is a summary of the estimated damages which occurred during the flood of August 11-14, 1940, classified according to type of damages.

Industrial	$179,475
Commercial	22,235
Domestic	15,700
Municipal	24,300
Highways	18,390
Railroads	10,000
Utilities	700
Agricultural	19,600
Total	$290,400

Damages from Flood of August 29, 1940

This flood was from one to three feet lower than the August 13 flood and caused some additional damages. A number of firms had just recovered from the earlier flood, others had only partially recovered; for these latter firms, this second flood caused little additional damage.


LEGEND
August 13,1940 flood overflow limits
August 30,1940 flood overflow limits
August 29,1940 headwater flood overflow limits
Stream gage
ASHEVILLE COTTON MILL
FRENCH BROAD RIVER
FRANK SILVERMAN SALVAGE CO.
HAJOCA CORP.
BILTMORE FREIGHT YARDS
WILLIAMS BROWNELL CO.
ASHEVILLE MICA CO.
NESS BROS. CO.
GALLIHER BROS. CO.
TUXEDO FEED CO.
COLONIAL DISTRIBUTING CO.
NATIONAL BISCUIT CO.
SWANNANOA
BILTMORE
SAYLES-BILTMORE BLEACHERIES INC.
MUNICIPAL GOLF COURSE
LAKE CRAIG DAM
CITY RECREATION PARK
OTEEN
Lake Craig
Gashes Creek
Sweeten Creek
TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT
STORMS OF AUGUST 1940
AREA FLOODED AT ASHEVILLE, N. C.
VICINITY OF BILTMORE
SCALE 0 1000 2000 3000 4000 FEET

As in the earlier flood, most of the damages occurred in the reach from Azalea to Biltmore.

The following is a summary of the estimated damages which occurred during the flood of August 29, 1940, classified according to type of damages.

Industrial	$ 18,675
Commercial	575
Domestic	550
Municipal	5,500
Railroads	2,500
Total	$27,800

Flood Protection Plan

The congestion on the flood plain of the Swannanoa River by industrial and commercial development practically precludes the possibility of controlling floods either by levees along the river or by enlarging the river channel. The control of the large flood peaks which develop on this stream would require very high levees or a very large channel, neither of which is practical under the existing conditions.

The most feasible method of flood control is by a detention reservoir located upstream from the highly developed area. An excellent site for such a reservoir exists immediately upstream from Azalea as shown on plate 13. This reservoir is called the Azalea Reservoir in this report. The reservoir plus some improvements in the capacity of the channel between the reservoir and the mouth of the river will provide adequate protection from Swannanoa River floods and is also a necessary part of any plan for reducing floods on the French Broad River through and downstream from the city of Asheville. The complete protection of Biltmore requires that French Broad River floods be controlled as well as those on the Swannanoa River to prevent backwater from the French Broad inundating Biltmore.

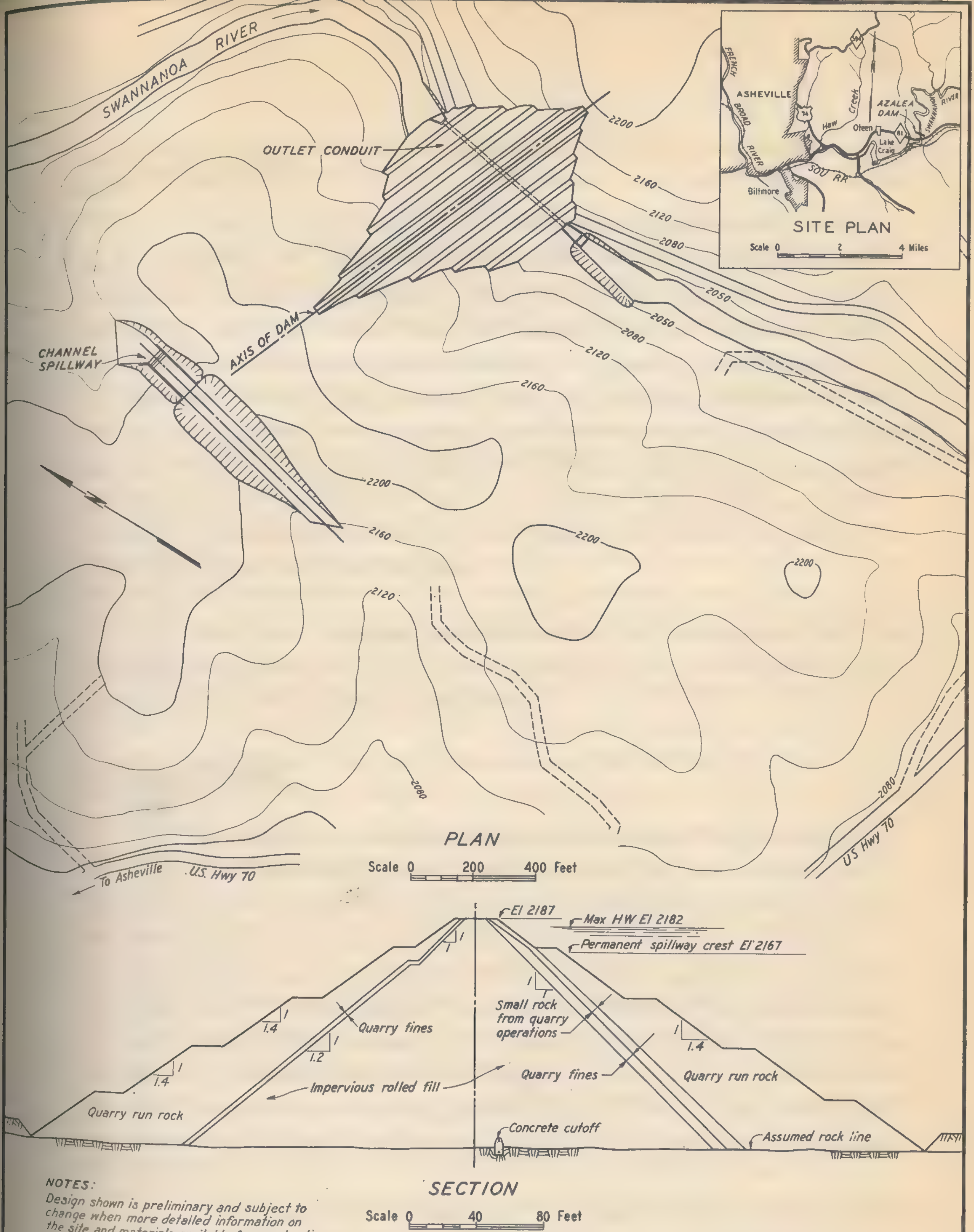
Flood protection for the upper Swannanoa above Azalea is not feasible under present conditions. A reservoir on North Fork was considered as a possibility but such a reservoir would not control enough of the watershed to justify its construction. Local protection works might prove desirable for the town of Swannanoa, Black Mountain, and Montreat but such works are not within the scope of this investigation.

Azalea Reservoir

It is proposed to construct a dam in a gorge section of the Swannanoa River, about one mile above the town of Azalea. Here the banks are steep and the bottoms along the river are quite narrow. The river in this locality turns away from the main highway and railroad up the Swannanoa Valley so that it is possible to build a dam to create a storage reservoir without interfering with the main highway and railroad. Upstream from the dam site, the river valley continues narrow for about 4 miles and then widens out, affording an excellent opportunity for a storage reservoir.

Plate 13 shows the location and extent of the reservoir. Plate 16 is a general plan of the Azalea Dam. The dam would be an earth fill type of structure. The reservoir above the dam would have capacity, with the water at the level of the crest of the spillway, to store runoff amounting to 12 inches from the watershed of 96 square miles upstream. The uncontrolled outlet conduit would have a capacity of 2000 cubic feet per second runoff with the water at spillway level. The spillway would be on the right bank and would discharge into Grassy Branch any runoff that could not be stored in the reservoir or discharged through the conduit. It is not expected that this spillway would ever come into use but if it should, it will be only at extremely long intervals of time.

The Azalea Reservoir with water at the maximum level would reach to just below the town of Swannanoa but would not flood any of that town. There are no railroads nor principal highways in this reservoir.



NOTES:

Design shown is preliminary and subject to change when more detailed information on the site and materials available for construction is obtained prior to construction.

Site topography taken from advance sheets of USGS-TVA topographic maps.
Low water at El 2045. Maximum height of dam 142 feet.
60-foot fuse plug embankment.
Twin outlet conduits, uncontrolled.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

GENERAL PLAN
AZALEA DAM
SWANNANOA RIVER

Channel Improvement

There are 35 square miles of drainage area downstream from the Azalea Reservoir, the runoff from which flows into the Swannanoa River through Haw Creek, Sweeten Creek, Gashes Creek, and some smaller streams. Ordinarily, the flood runoff from this uncontrolled area would not exceed the capacity of the present river channel. To guard against flooding of the Swannanoa Valley lands by runoff from this tributary area during extremely heavy storms, it is proposed that the river channel downstream from the reservoir be improved so that it would have a capacity of approximately 10,000 cubic feet per second. This would require some clearing, removal of bars or other minor work in the river channel but would not require the reconstruction of existing bridges.

Local flood problems such as exist on the creeks which drain the area downstream from Azalea Dam are not within the scope of this report and may be taken care of by local interests.

Protection Provided

The capacity of the Azalea Reservoir provides for storage of storm runoff approximately three times that which has resulted from any known flood of the past. The large additional storage capacity over that required to have safely controlled the floods of 1916, 1928, and 1940 provides an ample margin for floods of much greater magnitude. The 1791 flood was about five feet higher than the 1916 flood on the Swannanoa but nothing is known of the volume of flood runoff from this old flood. It is reasonable to conclude that with the large margin of storage above the runoff from the great flood of 1916, such a flood as that of 1791 could have been stored in the Azalea Reservoir without reaching maximum water level.

Downstream from the reservoir, the runoff in 1916, 1928, or 1940 would have been safely confined within the banks of the Swannanoa River. Assuming that French Broad floods are controlled to eliminate backwater in Biltmore, the industrial and commercial area through Biltmore and along the valley of the Swannanoa River would have complete protection against all floods.

IV. UPPER FRENCH BROAD VALLEY

The French Broad Basin above the mouth of the Swannanoa River drains an area of 800 square miles, much of which is rugged and mountainous. Threading through the middle of the watershed in a general northeasterly curving direction in a valley of unusually flat slopes for this region is the main French Broad River. Flanking the river on either side are several major tributaries of comparatively steep slopes emptying into the French Broad. Plate 1 shows the main stream and its tributaries.

The valley lands along the French Broad and its principal tributaries are for the most part fertile and are used for agricultural purposes. Particularly is this true for the land along the lower reaches of Mills River and in that portion of the French Broad Valley near the mouth of Mills River. These valley lands have gentle slopes and are well adapted to agriculture. Lying along the streams, however, they are subject to flooding with costly losses of crops. In July 1916, the entire valley below Rosman was overflowed by the greatest flood of record. Large damages resulted and repetition of such a flood today would cause losses of more than half a million dollars. There were also floods in August 1928, October 1932, and August 1940 which if repeated today would cause damages estimated at $208,000, $108,000, and $210,000 respectively. Other lesser floods cause considerable damages.

The broad bottoms of the main river and some of its tributaries, being for the most part of high fertility, are considered by agriculturists to be adapted to truck farming if the hazard of frequent overflows can be removed. Under present conditions there is a likelihood of crop damage on the average of about once every two years. If this hazard can be removed from a considerable portion of these valuable agricultural lands, then it will be possible to intensify cultiviation of the lands with consequent large benefits. Under present practice, the greatest acreage of bottom lands is devoted to corn. On some farms which have suffered severely from floods, the lowest and most fertile land near the river is being used for pasture because

of the flood hazard. County Agent Glazener of Transylvania County states that with protection from floods these low lands can be developed into a high yield truck crop area with a local market in the expanding industrial areas nearby. An example of the value of crops that may be grown in the French Broad Valley is a field of iris bulbs which were overflowed by a moderate flood in May 1942 with a complete loss to the owner of $800 per acre.

Study of the flood problems of the Upper French Broad Valley shows that flood protection by storage reservoirs offers the best solution. To provide flood protection for all of the agricultural lands in the valleys of the Upper French Broad River and its main tributaries is not feasible because there are insufficient sites for storage reservoirs upstream from all of the lands. However, suitable storage reservoir sites exist so that agricultural flood protection can be provided for a large part of the agricultural valley lands and this is the most feasible thing to do. Under this plan, which is part of the Regional Plan, storage reservoirs of the detention basin type would be built on Cane Creek, Mud Creek, Little River, Davidson River, Mills River, and on the French Broad above Brevard. These reservoirs and the part which each has in the Regional Plan for flood protection are described in the succeeding sections of this report.

1. UPPER FRENCH BROAD VALLEY

The Flood Situation

Pioneer settlers came into the Upper French Broad country in the latter part of the 18th Century. Development of the fertile bottom lands in the stream valleys has continued since then and at the present time the greater part of these lands are in cultivation.

The largest towns along the river in this basin are Brevard and Rosman. Brevard is not damaged by high water except by interruptions of communications, but the lower part of Rosman is flooded by any major rise. Industries at Rosman and near the mouth of Davidson River in the town of Pisgah Forest are affected by floods. Farm homes are generally located

FIGURE 10 — GREEN BEAN FIELD FLOODED AUGUST 17, 1939

This field of green beans in the valley of the French Broad River near Butler Bridge was a complete loss after being flooded. Truck crop losses in the August 1940 floods ranged from $100 to more than $300 per acre.

FIGURE 11 — BOTTOM LANDS ALONG LOWER REACH OF CANE CREEK

The bottoms along this reach are about a half mile wide and are overflowed whenever Cane Creek is in flood. The creek follows the thin line of trees in the middle background.

well above high water. Highways have been raised since the 1916 flood so that paved roads are affected only in a few places in the vicinity of Penrose and Horseshoe. Gravel and other secondary roads are damaged by large floods. The tracks of the Toxaway Branch of the Southern Railway follow the edge of the overflow area and are subject only to small losses except at crossings of the river and main tributaries. The heaviest damages are those to agriculture due to crop losses.

The River and Its Valley

The slopes of the channel of the French Broad River through the valley are relatively flat for a stream in this region. For the first 10 miles above Hominy Creek the slope is about 7 feet to the mile but from there upstream for the next 35 miles, the slope is only about 2 feet to the mile. Continuing upstream for about 15 miles, the slope is a little less than 4 feet to the mile to about four miles below the town of Rosman where the slope increases to about 7 feet to the mile. Above Rosman, where the river divides into its four forks, slopes are characteristically steep as in headwater mountain streams.

Combined with the flat slopes is a river channel of small capacity which overflows its banks even in small floods. The flood plain has gentle slopes so that overflows spread out over considerable areas. The flood plain is a succession of wide areas ranging in width up to about one mile alternating with areas of narrower width.

Runoff from the extreme headwaters converges at Calvert with the confluence of the North, Middle, West, and East Forks of the French Broad. Runoff here is rapid and crests occur in from three to five hours after a storm. Downstream from Calvert, due to the flat river slopes, flood crests often take 24 to 36 hours to travel from Calvert to Blantyre, a distance of only 30 miles. Crests at Bent Creek and Asheville ordinarily precede those at Blantyre. The relative flatness of the river throughout the middle part of the basin causes enough retardation of the crests of floods from the extreme headwaters so that the crests from the middle tributaries reach Asheville before the crests occur at Blantyre.

Summary of Flood History

The results of investigations of past floods in the Upper French Broad Basin are summarized as follows:

1. The flood of July 16, 1916, surpasses any other of which record or legend was found.

2. Other important floods occurred in June 1876, January 1906, August 1928, August 13 and August 30, 1940.

3. Major floods are almost always occurrences of summer and early fall, the one of January 1906 being a conspicuous exception.

4. The flood plain includes considerable areas of broad, flat bottoms subject to overflow at relatively low flood stages, and ranging up to one mile in width.

5. Flood damages are mostly agricultural; damage also occurs to highways and bridges, railroads and industries.

Flood Heights and Occurrences

Table 7 is a compilation of the crest elevations at Blantyre for damaging floods for which an approximate stage could be established. Blantyre is located about midway of the length of the valley and flood heights there reflect flood conditions in the Upper French Broad Valley.

Magnitude of Past Floods

Data are not available from which to estimate the flood volumes and peak rates of flow for all floods but there are sufficient data at four stations on the Upper French Broad River to do this for the floods of 1916, 1928, and 1940.

TABLE 7

CREST STAGES OF DAMAGING FLOODS

AND

ESTIMATED FLOOD DAMAGES

WITH DEVELOPMENT AS IN 1941 CAUSED BY REPETITION OF PAST FLOODS

UPPER FRENCH BROAD RIVER

Date of Flood			Crest Gage Height At Blantyre	Elevation (1936 Sup. Adj.)	Total Flood Damages
April		1791)	Large floods are believed to have occurred on these dates with probable stages ranging between 20 and 25 feet.		
August		1796)			
		1810)			
May		1845)			
August		1850)			
August		1852)			
February		1875	17.0	2077.3	$ 15,900
June		1876	23.0	2083.3	207,600
October	17,	1879	19.0	2079.3	53,400
Sept.	13,	1893	18.0	2078.3	33,100
March	15,	1899	17.0	2077.3	15,900
March	19,	1899	17.0	2077.3	15,900
May	22,	1901	20.0	2080.3	78,800
February	28,	1902	19.0	2079.3	53,400
July		1905	21.0	2081.3	107,900
January	23,	1906	22.0	2082.3	157,900
August	31,	1910	21.0	2081.3	107,900
May	23,	1916	17.0	2077.3	15,900
July	10,	1916	22.0	2082.3	157,900
July	16,	1916	27.2	2087.5	531,900
October	25,	1918	17.0	2077.3	15,900
October	29,	1918	20.0	2080.3	78,800
August	16,	1928	22.90	2083.2	207,600
March	14,	1929	19.2	2079.5	53,400
October	17,	1932	20.68	2081.0	107,900
March	15,	1934	17.32	2077.6	15,900
January	10,	1935	18.29	2078.6	33,100
April	7,	1936	18.85	2079.2	53,400
October	17,	1936	17.43	2077.8	15,900
January	3,	1937	17.76	2078.1	33,100
October	20,	1937	18.83	2079.2	53,400
August	19,	1939	17.40	2077.7	15,900
August	13,	1940	21.88	2082.2	157,900
August	31,	1940	19.31	2079.6	53,400
Total					$2,449,000

Table 8 gives information for these floods together with pertinent rainfall and runoff data.

TABLE 8

FLOOD FLOW AND RUNOFF

UPPER FRENCH BROAD RIVER

Date		Drainage Area	Average Rainfall	Gage Height	Peak Discharge Amount	Peak Discharge Per Sq.Mi.	Surface Runoff		Runoff to Rainfall
		Sq.Mi.	Inches	Feet	c.f.s.	c.f.s.	Ac.Ft.	In.	Percent
				At Rosman					
July	1916	67.9	8.7	13.9	18,200	268	13,500	3.7	43
August	1928		-	12.5	11,000	162	-	-	-
Aug. 13,	1940		11.2	11.78	9,040	133	9,400	2.6	23
Aug. 30,	1940		9.2	11.88	9,400	138	8,200	2.3	24
				At Calvert					
July	1916	103	-	13.6	22,000	214	-	-	-
August	1928			13.0	17,300	168			
Aug. 13,	1940		11.7	11.66	12,300	120	19,000	3.5	30
Aug. 30,	1940		8.3	10.85	9,400	91	15,600	2.8	34
				At Blantyre					
July	1916	296	12.7	27.2	50,700	171	131,000	8.3	66
August	1928		-	22.9	26,000	88	-	-	-
Aug. 13,	1940		11.4	21.88	20,800	70	55,000	3.5	31
Aug. 30,	1940		8.1	19.31	10,900	37	33,600	2.1	26
				At Bent Creek					
July	1916	676	12.6	27.3	105,000	155	304,000	8.4	67
August	1928			16.1	38,000	56			
Aug. 13,	1940		9.9	12.60	23,600	35	93,700	2.6	26
Aug. 30,	1940		7.6	11.07	18,900	28	75,300	2.1	28

Flood Damages

Table 7 gives estimated flood damages in the Upper French Broad Basin above Asheville assuming that known floods of the past were to recur with improvements as they now are. About 90 percent of the damages are downstream

from the proposed Catheys Creek Reservoir on the Upper French Broad River. Appendix B gives more details of flood damages.

Damages for Repetition of July 16, 1916, Flood

This flood was the highest ever experienced on the Upper French Broad River and caused tremendous damages. In addition to enormous property losses, numerous landslides destroyed property, changed water channels, and killed two people. Many highway bridges were swept away and railroad service was interrupted for five days. All crops in the fertile river bottoms were a total loss and considerable damage to land resulted from erosion and scour.

Should a flood of this magnitude and height occur today, it is estimated that the probable damage would be $532,000. This would be classified as follows:

Agricultural losses to crops and farm lands - - - -	$364,000
Commercial losses - - - - - - - - - - - - - - - - - -	3,900
Domestic damages to homes and buildings - - - - - -	3,600
Highway damages - - - - - - - - - - - - - - - - - - -	104,000
Railroad damages - - - - - - - - - - - - - - - - - -	44,000
Utility damages - - - - - - - - - - - - - - - - - - -	12,500

Flood Damages for Repetition of August 1928 or June 1876 Floods

These two floods were approximately equal in height. During the flood of August 1928 the water at Rosman almost reached the heights of 1916. This was the second highest flood of record on the Upper French Broad. Train service into Brevard was interrupted for four days. Flood water was 6 feet deep on parts of the Brevard-Hendersonville road and covered the Toxaway Branch of the Southern Railway to greater depths. It is estimated that the losses during a flood such as that of August 1928, if repeated today, would be about $208,000. These are classified as follows:

Agricultural losses to crops and lands - - - - - -	$183,000
Domestic damages - - - - - - - - - - - - - - - - - -	500
Highway damages - - - - - - - - - - - - - - - - - -	14,000
Railroad damages - - - - - - - - - - - - - - - - - -	3,000
Utility damages - - - - - - - - - - - - - - - - - -	7,500

Damages Resulting from Floods of August 1940

The flood of August 13, 1940, was about 5-1/2 feet lower than that of 1916 at Blantyre and flooded a large part of the fertile bottoms in the Upper French Broad Valley, resulting in damages, principally to crops, of $158,000. The flood of August 30, 1940, cuased only about $4,200 in additional damages since most of the losses had already been suffered during the first flood. The damages, according to type, in the August 13 flood are as follows:

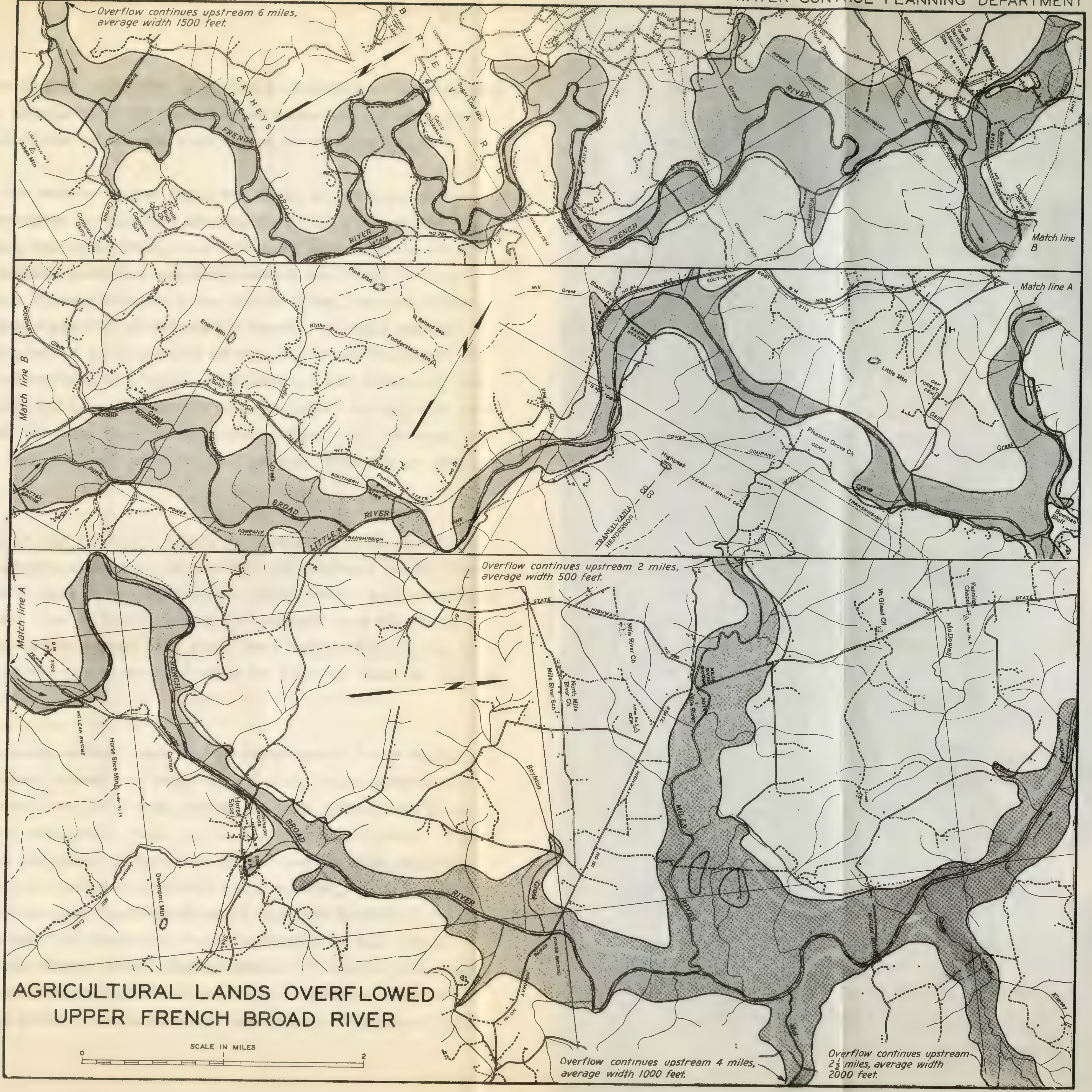
Agricultural losses to crops and lands - - - - - -	$144,300
Commercial damages - - - - - - - - - - - - - - - - - -	1,000
Domestic damages - - - - - - - - - - - - - - - - - -	500
Highways and bridges - - - - - - - - - - - - - - - -	9,900
Railroad -	1,500
Utilities -	800

Wherever truck crops were being raised in the valley, losses per acre were high. For potatoes the losses were from $80 to $103 per acre, for green beans, from $167 to $211 per acre, for lima beans, $316 per acre, and for other truck crops from $68 to $226 per acre. Losses on corn, soy beans, lespedeza, clover, and other hay crops averaged about $20 per acre.

Flood Protection Plan

Protection from floods of the agricultural lands in the valleys of the Upper French Broad and its principal tributaries presents a very difficult problem. On both sides, the valley lands are bounded by rugged terrain, much of which is mountainous and steep. Surface runoff from these surrounding lands quickly runs off on to the lower lands which make up the valley of the French Broad. As a result of the flat slope and comparatively small water carrying capacity of the river channel, floods overflow the banks and spread over the adjacent valley lands even during small floods. Plate 17 shows the agricultural lands overflowed along the Upper French Broad River.

To provide complete flood control protection for the agricultural lands would be very costly and of doubtful feasibility. However, it is not necessary to provide the complete protection for agricultural lands that is necessary in protecting city property where potential losses are much greater



AGRICULTURAL LANDS OVERFLOWED
UPPER FRENCH BROAD RIVER

and where loss of life is more probable. Occasional overflows of agricultural lands at intervals of perhaps 10 to 15 years may be tolerated and will still permit the development of the lands to a high degree of cultivation.

To protect the fertile valley lands, the flood waters from as much of the surrounding watersheds as possible must be kept from getting into the flat valley trough along the main river. The tributary watersheds which are large enough in size to make reservoir control feasible are those of Cane Creek, Mud Creek, Little River, Davidson River, Mills River, and the headwaters of the French Broad itself. Reservoirs proposed for these streams control 472 square miles which is 75 percent of the area above the mouth of Cane Creek. Even by controlling this large percentage of the watershed, the runoff from the uncontrolled watershed is still large enough to slightly overtax the capacity of the existing river channel during floods of the magnitude of that of mid-August 1940. Floods somewhat smaller than this can be carried in the channel.

On the basis of the record of floods at Blantyre, it is estimated that with the six reservoirs operating, part of the agricultural valley lands would be overflowed about once in thirteen years. Even during such occasional overflows, the depth and time of flooding would be reduced from what these would be under natural conditions, and some lands that would otherwise be flooded would be protected. The mid-August flood at Blantyre would be reduced about 7 feet.

The data available on the lands in the Upper French Broad Valley are not sufficient to permit a detailed study of the local flood problems of these lands. Such a study should be made eventually as a part of the determination of the ultimate reclamation that can be given to these lands. This would develop the needs and possibilities for channel enlargement, building of levees, diversion of hill water by channels and floodways, open drainage ditches, underdrainage, or other local works which might be desirable and feasible in some locations. It might also prove desirable at some future time, if the valley lands fulfill their potentialities, to control the runoff from some of the smaller drainage areas such as that of Boylston Creek by storage reservoirs. In order to satisfactorily investigate these problems,

good topographic maps of the Upper French Broad Valley and the valleys of the principal tributaries would be required. These maps should show elevation differences of one foot and should be complete with respect to existing culture.

Catheys Reservoir

The dam to create this reservoir would cross the French Broad River valley near the mouth of Catheys Creek about 4 miles southwest of Brevard. At this location, the hillsides bordering the valley are relatively close together and the river bottom is comparatively narrow making a favorable location for a dam. Plate 18 is a map of the French Broad watershed upstream from Catheys Creek and shows the proposed reservoir.

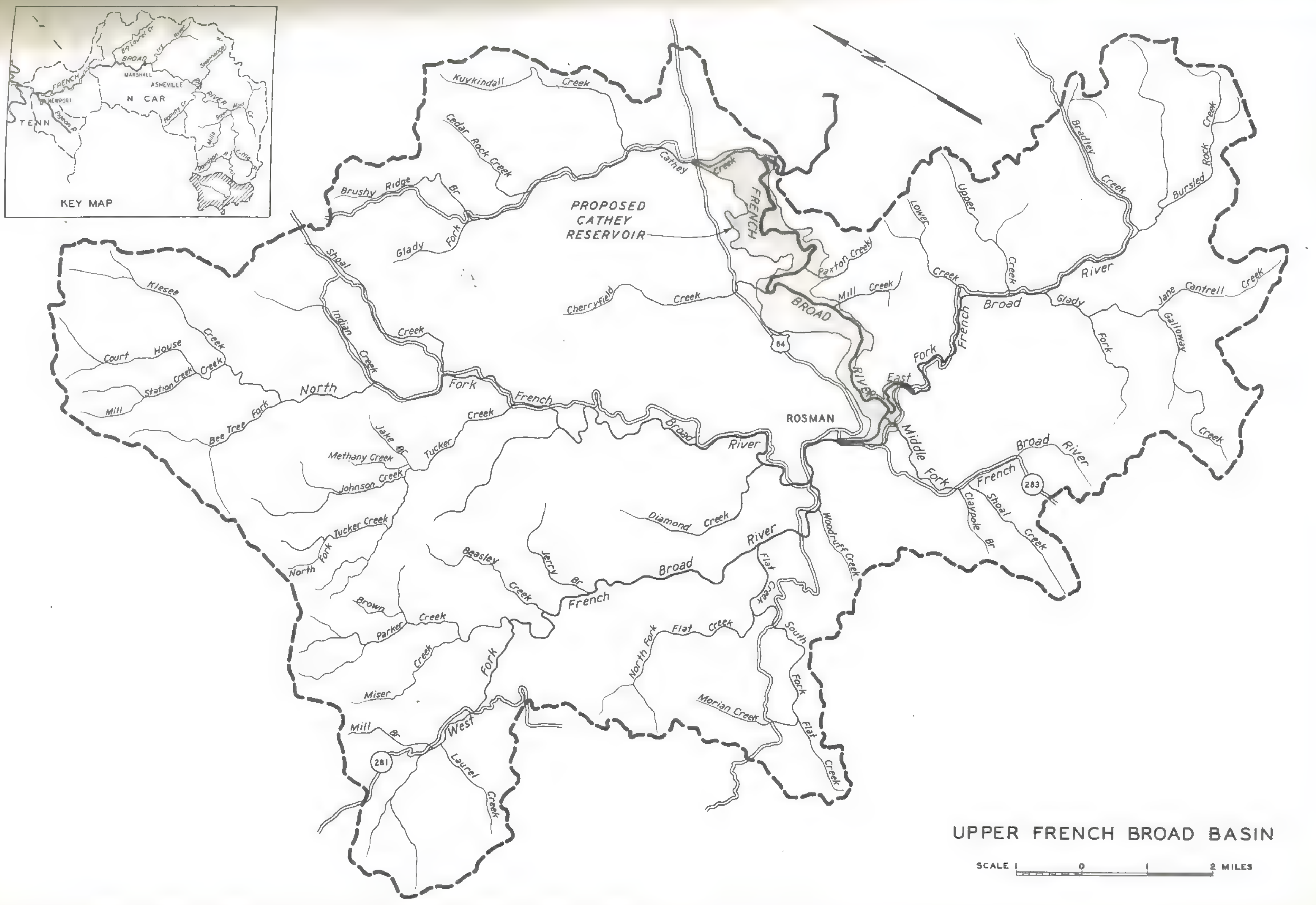
Plate 19 is a general plan showing location and other details. The dam is planned to be an earth fill type of structure. At the level of the spillway crest, the reservoir above the dam would have capacity to store run-off amounting to 6 inches from the watershed of 131 square miles upstream. The gate controlled outlet tunnel through the dam would have a capacity of 10500 cubic feet per second with the water level at the spillway.

Channel Improvements

Supplementing the storage reservoirs, it is proposed to carry out minor improvement work in the channel of the French Broad River from Asheville to the Catheys Reservoir. This would include clearing, removal of bars and obstructions and other minor work in the river channel which would be helpful in increasing the carrying capacity.

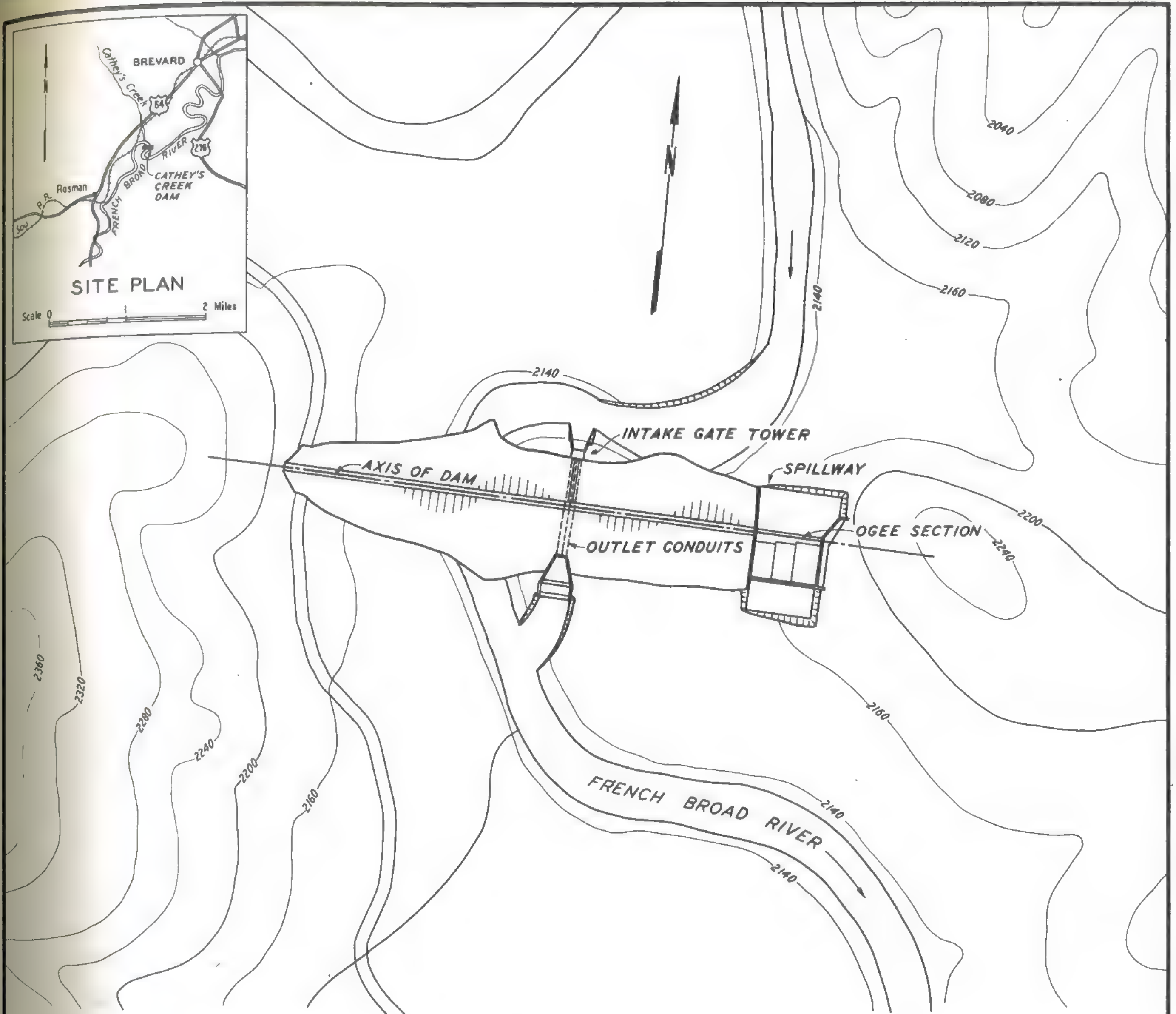
Protection Provided

As previously noted, the six proposed detention reservoirs, including Catheys Reservoir, are designed to provide satisfactory flood protection for agricultural lands. Those floods which now occur about once every two years would be practically eliminated. Larger floods such as those of 1928 and August 1940 would also be controlled so that damages to agricultural lands would be materially reduced.



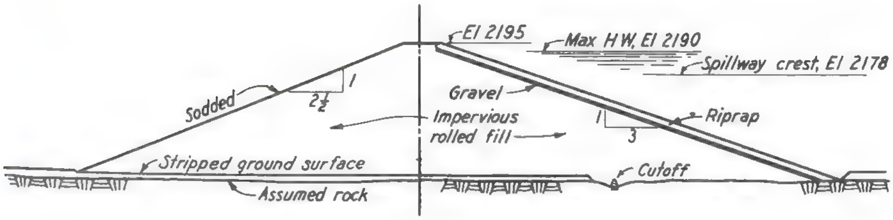
UPPER FRENCH BROAD BASIN

SCALE 0 1 2 MILES



PLAN

Scale 0 200 400 Feet



SECTION

Scale 0 50 100 Feet

NOTES:

Design shown is preliminary and subject to change when more detailed information on the site and materials available for construction is obtained prior to construction.

Site topography taken from advance sheets of USGS-TVA topographic maps.

Low water at elevation 2124. Maximum height of dam, 71 feet.

160-foot concrete overflow spillway section.

Twin outlet conduits, gate controlled.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

GENERAL PLAN
CATHEY'S CREEK DAM
FRENCH BROAD RIVER

During a great flood such as that of July 1916, the storage capacity at spillway levels of some of the reservoirs would be exceeded. However, such floods occur only at long intervals of time and are not intended to be provided against in flood protection for agricultural lands. The damage during large floods would be materially reduced by the construction of the proposed six reservoirs.

2. CANE CREEK

The Flood Situation

One of the six upper basin storage reservoirs is planned to be on Cane Creek near the mouth of Robinson Creek just upstream from the Asheville-Hendersonville Airport. Plate 20 is a map of the Cane Creek basin on which the location of the reservoir is shown.

Cane Creek drains a generally rugged watershed of 87 square miles to the southeast of Asheville. The creek flows into the French Broad about 15 miles upstream from that city. This watershed is not as mountainous as the Swannanoa or the areas which head in the mountains on the west side of the French Broad Valley. Elevations in the basin range from about 2000 feet to 3500 feet. The main line of the Southern Railway south from Asheville and U. S. Highway 25 cross the creek about 2-1/2 miles upstream from its mouth. A good gravel road parallels the stream for nearly its entire course following along the upper edge of the valley of the creek. U. S. Highway 74 crosses about twelve miles upstream from the mouth.

The area is dominantly agricultural. The bottom lands in the valley of the creek are for the most part fertile and produce good crop yields excepting for the extreme lower portion of the basin where poor natural drainage makes the lands chiefly useful for pasture. The Asheville-Hendersonville Airport is located in a broad flat in the Cane Creek Valley. This airport has been improved since the floods of 1940 and is now an important airport.

The lands in the valley along Cane Creek are subject to overflow with considerable damage to crops. The airport, highways, and railroads are

also subject to overflow damage during large floods. Flood runoff from this stream also contributes to flooding in the French Broad Valley and at Asheville.

The Creek and Its Valley

Cane Creek extends through the middle of its drainage area with small tributaries coming in from both sides. Near the mouth of the creek the fall of the stream is about nine feet per mile. This increases towards the upper end of the creek to more than 20 feet per mile. Banks are generally from five to eight feet above low water.

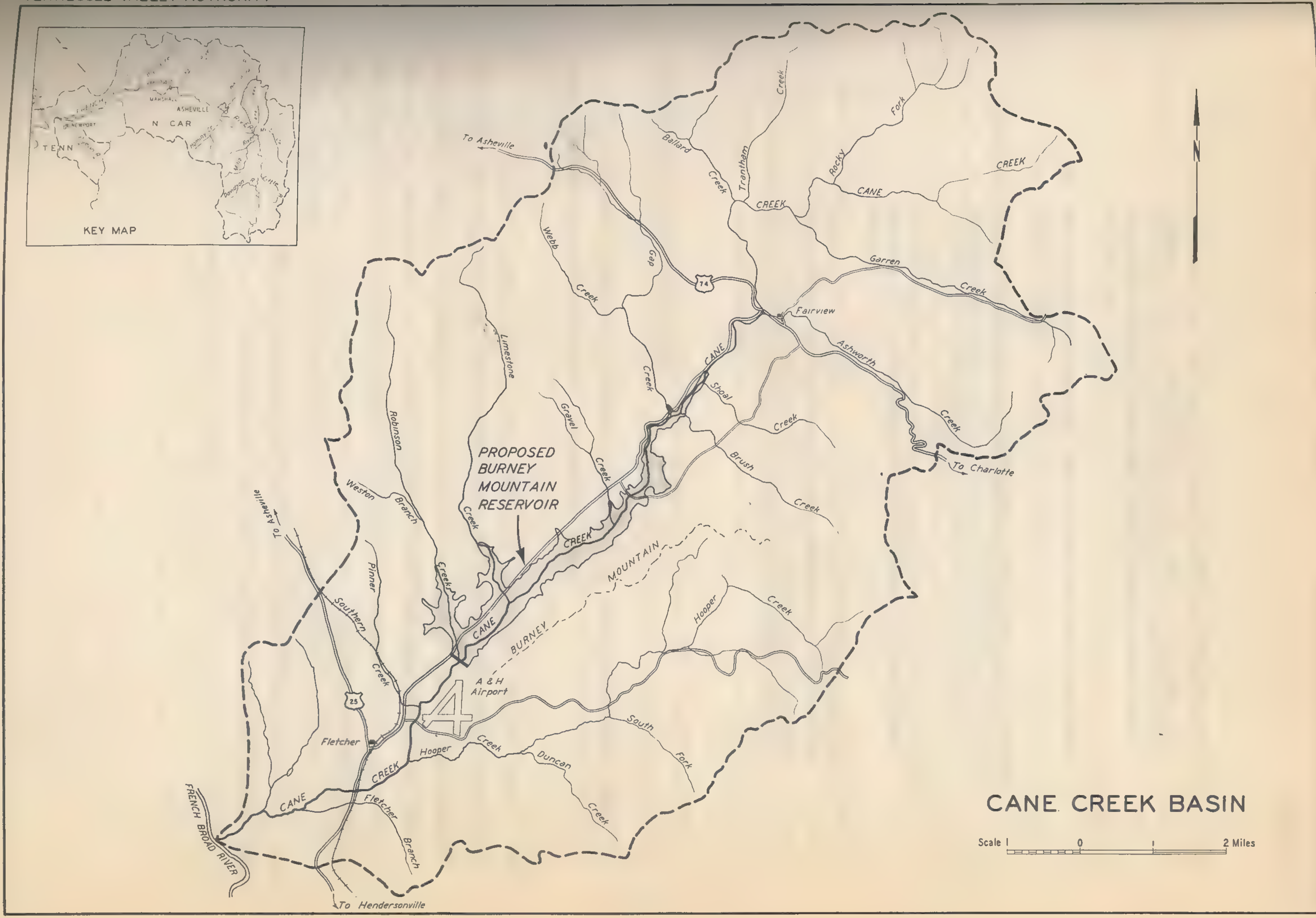
Asheville-Hendersonville Airport

The Asheville-Hendersonville Airport is located immediately downstream from Robinson Creek. The August 1940 floods covered part of the existing runway and a considerable part of the adjacent land which has later been taken into the airport. After the 1940 floods a program for enlargement and improvement of the airport was undertaken by the Works Project Administration, the Civil Aeronautics Authority, and the city of Asheville. The plans for this work provide for the raising of the existing runway and constructing two new runways to elevations about equivalent to the height of the 1940 flood but some five feet below the 1916 flood. Some channel improvements, chiefly straightening, are also planned in the existing channel of Cane Creek. The airport lies immediately below the proposed reservoir on Cane Creek and would be benefited by the protection afforded.

Summary of Flood History

The results of the investigations of past floods in the Cane Creek Basin are summarized as follows:

1. The flood of July 1916 far exceeds any other in the history of the basin, surpassing the next highest flood by amounts ranging from 10 feet near the mouth to two feet at Fairview where the channel is much steeper.



CANE CREEK BASIN

2. Three other floods, the August 1928 and the two in August 1940, reached nearly the same stage and, except for the flood of 1916, appear to have been as great or greater than any other floods since the valley was settled.

3. The largest floods on Cane Creek have resulted from summer storms.

4. Wide overflow occurs along the lower ten miles of the creek during all major rises. Below Mile 5, the width of overflow exceeds half a mile in several places.

5. Backwater from the French Broad River affects the lower portion of the valley for a distance of about three miles.

6. Principal damage is to crops, to U. S. Highway 25 and the tracks of the Asheville-Spartanburg Division of the Southern Railway and to the Asheville-Hendersonville Airport which is subject to overflow during major floods.

Flood Heights and Occurrences

Table 9 shows the elevations reached by damaging floods since 1876 on Cane Creek at the mouth of Robinson Creek.

Little information could be obtained on floods prior to 1916. The flood of that year so far exceeded any earlier floods that others were soon forgotten. Mr. L. C. Clayton states that he remembers hearing his grandfather and father talk of floods but none of these extended over more than the "low bottoms" and were probably not as bad in any case as the flood of August 30, 1940. In speaking of early floods, Mr. Clayton includes the 1876 flood, important on the French Broad, as not particularly outstanding on Cane Creek. Mr. Clayton's memory of the floods he has witnessed extends back about 60 years and he is certain none in that time were as great as the August 30, 1940, flood excepting that in 1916.

TABLE 9

CREST STAGES OF DAMAGING FLOODS

AND

ESTIMATED FLOOD DAMAGES

WITH DEVELOPMENT AS IN 1941 CAUSED BY REPETITION OF PAST FLOODS

CANE CREEK

Date of Flood		Elevation at Mouth of Robinson Creek	Total Flood Damage	Damages Below Dam Site
June	1876	2094	$ 23,150	$ 9,300
September	1893	2093	13,200	6,000
May	1901	2092	7,400	3,500
December	1901	2092	7,400	3,500
February	1902	2092	7,400	3,500
August	1910	2094	23,150	9,300
July 16,	1916	2101.4	101,200	72,200
April 14,	1923	2091.5	7,400	3,500
Aug. 16,	1928	2093.6	23,150	9,300
Aug. 13,	1940	2093.6	23,150	9,300
Aug. 30,	1940	2095.1	25,200	9,900
Total - - - - - - - - - - - - - - - - - -			$261,800	$139,300

Since there are no gaging stations on Cane Creek, the mouth of Robinson Creek, at Mile 4.95, was selected as a point of comparison for the various floods. Minimum damaging stage was taken as about two feet below the flood of August 13, 1940, or elevation 2091.5.

Magnitude of Past Floods

Data are available from which to estimate the flood volumes and peak rates of flow for the floods of July 16, 1916, August 1928, August 13, 1940, and August 30, 1940. Table 10 gives this information for these floods.

TABLE 10

FLOOD FLOW AND RUNOFF

CANE CREEK AT MOUTH OF ROBINSON CREEK

(Drainage Area 60 Square Miles)

Date	Average Rainfall	Elevation	Peak Discharge		Surface Runoff		Runoff to Rainfall
			Amount	Per Sq.Mi.			
	Inches	Feet	c.f.s.	c.f.s.	Ac.Ft.	In.	Percent
July 16, 1916	16.5	2101.4	24,000	400	39,800	12.4	75
Aug. 1928	-	2093.6	2,000	34	-	-	-
Aug. 13, 1940	5.2	2093.6	2,030	34	3,840	1.2	23
Aug. 30, 1940	6.4	2095.1	3,450	58	5,600	1.8	27

Flood Damages

Table 9 gives estimated flood damages in the Cane Creek Basin for known floods of the past, assuming that these were to recur with improvements as they were in 1941. Damages are estimated for the stream as a whole and for the part downstream from the proposed Burney Mountain Reservoir. Due to the scarcity of flood information on this stream, it is probable that there have occurred a number of minor floods which would cause damages. Damages are about equally divided above and below the dam site. Appendix B contains more information on damages.

Damages for Repetition of July 16, 1916, Flood

This flood far exceeds all others in the known record of floods on Cane Creek and was greater in the Cane Creek and the adjoining Mud Creek watershed than anywhere else in the Upper French Broad region. All of the bottom lands were inundated, overtopping many of the stream banks by more than eight feet. Such a flood repeated under present conditions would flood the greater part of the improved Asheville-Hendersonville Airport. The highway and railroad fills which cross the valley at Fletcher would be overtopped by from 10 to 14 feet and would consequently suffer considerable damages. Farm crops would be

a total loss and farm roads and bridges would be damaged. Total estimated losses would be $101,000, approximately 40 percent of which would be agricultural damages due to loss of crops and damages to land. About one-half of the losses would be to highways and railroads.

Damages from Floods of August 1940

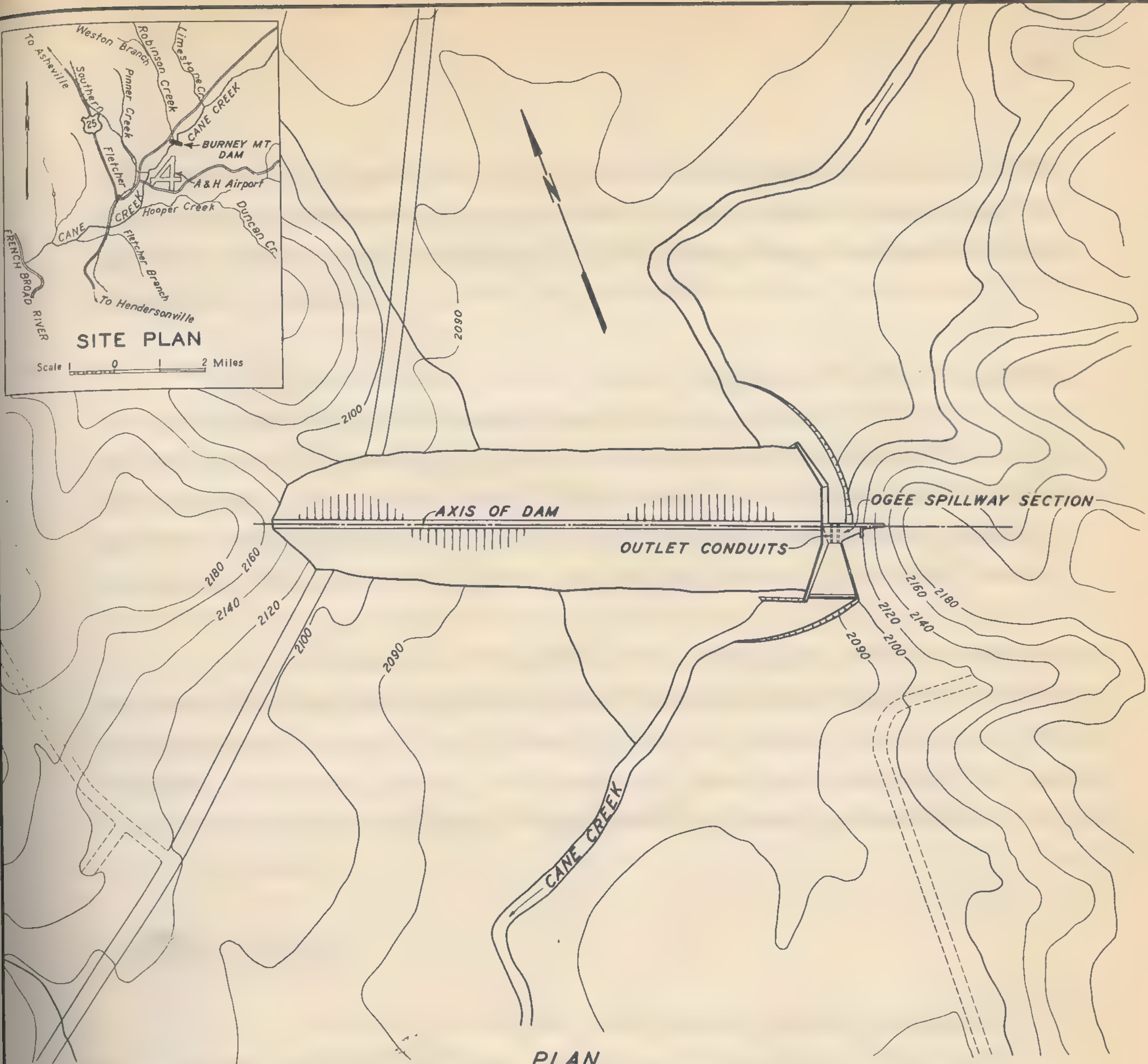
The flood of mid-August 1940 resulted in damages in the Cane Creek Basin estimated at $23,000. Practically all of this was to crops and agricultural improvements. The flood of August 30 caused only minor additional damages as the earlier flood had already damaged crops and other property in the valley. Damages per acre for crops lost were heavy, particularly for truck crops. Losses for green beans were $206 per acre, for lima beans $260 per acre, for potatoes $116 per acre, for corn and hay about $20 per acre.

Flood Protection Plan

The large volume of flood runoff from Cane Creek combined with the comparatively narrow width of bottom lands along the creek precludes flood protection for this valley by eigher levees or channel improvements. Such methods of protection would not be effective in reducing floods at Asheville and in the French Broad Valley. A storage reservoir offers the most suitable means of controlling floods on Cane Creek. In the upper portion of the watershed, the slopes of the stream valley are steep and a reservoir there would not provide sufficient storage. Such a reservoir would control only a small drainage area. The most feasible site for a storage reservoir with sufficient capacity to provide the necessary amount of flood control on Cane Creek is that upstream from a dam at the mouth of Robinson Creek. A reservoir at this location would not provide protection for the agricultural lands upstream from the dam but, operated as a detention basin, these lands could continue to be used in the future for general farming purposes.

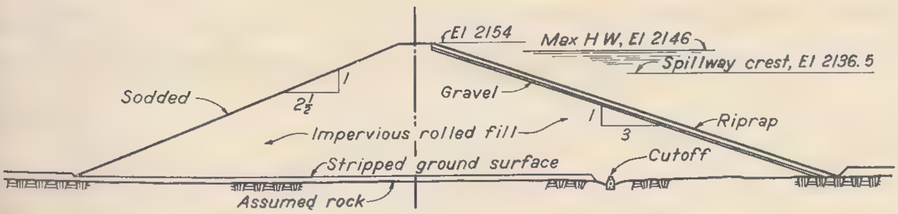
Burney Mountain Reservoir

The dam to create this reservoir is just upstream from the Asheville-Hendersonville Airport. Plate 20 shows the location and extent of



PLAN

Scale 0 200 400 Feet



SECTION

Scale 0 50 100 Feet

NOTES:

Design shown is preliminary and subject to change when more detailed information on the site and materials available for construction is obtained prior to construction.

Site topography taken from advance sheets of USGS-TVA topographic maps.

Low water at El 2086. Maximum height of dam, 68 feet.

100 foot wide ogee spillway section.

Two outlet conduits through concrete section, gate controlled.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

GENERAL PLAN
BURNEY MOUNTAIN DAM
CANE CREEK

the reservoir. The south end of the dam would tie into the tip of Burney Mountain and the reservoir is designated in this report by that name. At this site, the sides of the valley are relatively steep and the valley is comparatively narrow.

Plate 21 is a general plan of the dam. The dam is planned to be an earth fill type of structure. With the water at the level of the spillway crest, the reservoir above the dam would have capacity to store run-off amounting to six inches from the watershed of 60 square miles upstream. The gate controlled outlet conduit through the dam would have a maximum capacity of 5000 cubic feet per second with the water at spillway level.

The Cane Creek watershed had a tremendous flood runoff during the great flood of 1916 and the proposed Burney Mountain Reservoir would not have been large enough to have stored all of the water. The spillway would have come into action during that flood and would have discharged the surplus flood water back into the creek below the dam without endangering the safety of the structure.

Protection Provided

The lands in the Cane Creek Valley downstream from the dam would receive agricultural flood protection. In addition, the recently improved Asheville-Hendersonville Airport would be protected. Functioning as a part of the complete flood protection works, the Burney Mountain Reservoir would contribute to the protection of Asheville and the French Broad Valley.

3. MILLS RIVER

The Flood Situation

One of the storage reservoirs in the Regional Plan for flood control, is proposed for Mills River a few miles upstream from the mouth. Plate 22 is a map of the Mills River Basin on which the reservoir is shown.

The floods on this river are particularly destructive to the crops on the agricultural lands along the lower portion of the river and have retarded the development of these lands for their maximum utilization. Mills River also contributes to floods in the French Broad Valley and at Asheville and downstream points.

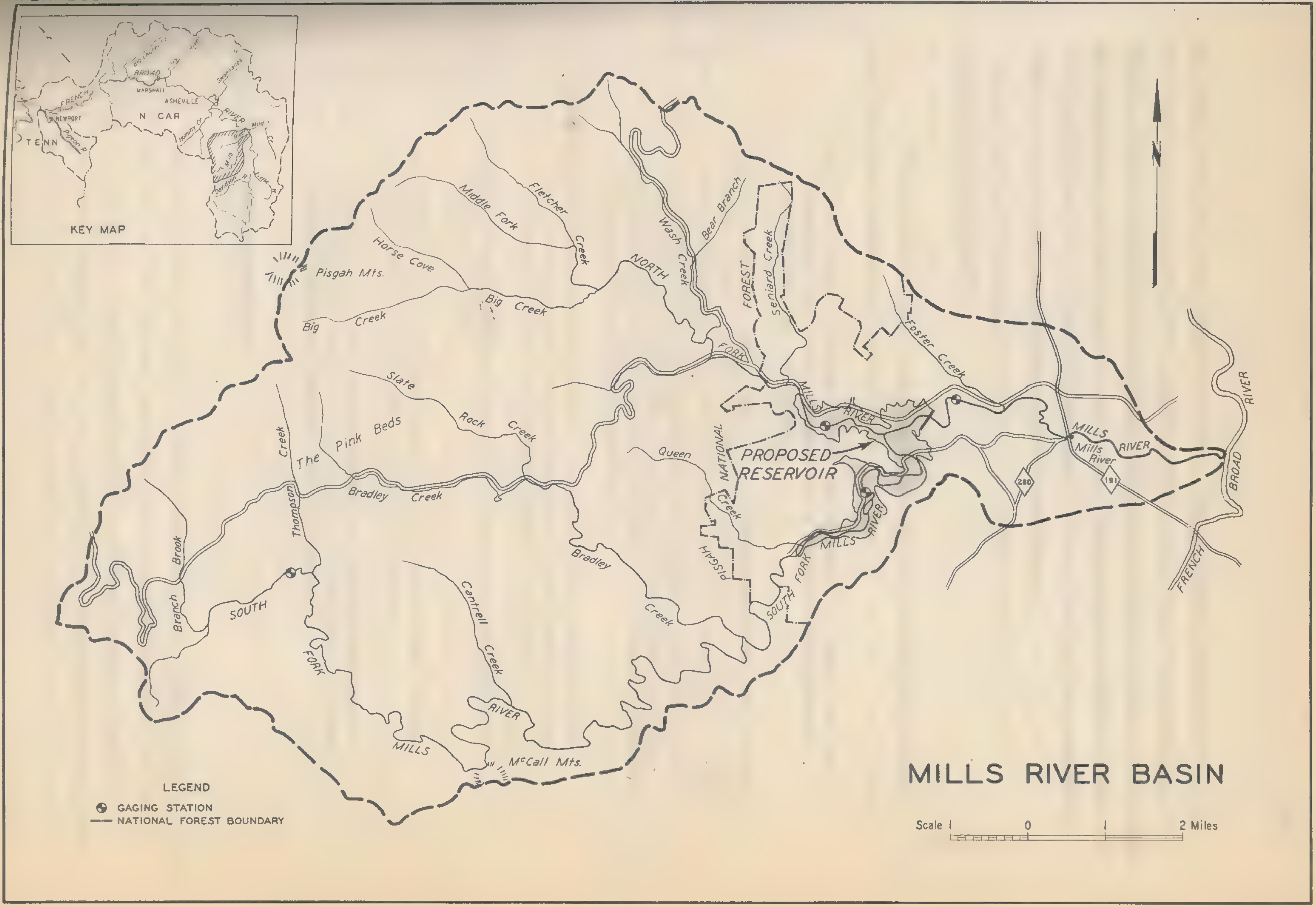
Named for William Mills, an early settler, Mills River is one of the larger of the headwater tributaries of the French Broad River. The watershed has an area of 74 square miles, most of which is rugged and mountainous. The river empties into the French Broad 22 miles above Asheville. Mt. Pisgah, elevation 5300, is on the western border of the watershed. Elevations in the Mills River Valley near the mouth of the river are approximately 2000.

The greater part of the watershed is heavily wooded and is now in the Pisgah National Forest. Nearly all the valley above the junction of the forks, then in excellent timber, was acquired by George W. Vanderbilt about 1895. Lumbering proceeded on a small scale from then until 1914 when Vanderbilt contracted the lumbering of his land to the Carr Lumber Company. This firm worked the Vanderbilt holdings from a plant built near Brevard. A railroad was built into the Mills Valley from Boylston Creek and extended, as operations continued, up the South and North Forks to their headwaters. Operations continued until the early 1930's.

The lands along the lower part of Mills River are among the most highly productive and valuable agricultural lands in the French Broad region. These are adaptable to truck crops of high value although many of them are not being so used because of the hazard of floods. In past years, some farms in this valley have raised crops for seed purposes. North Carolina State Highway 280 crosses the river about two miles above the mouth. Good gravel roads extend on both sides of the river following up the valley and its forks. Floods are particularly damaging to crops.

The River and Its Valley

Through the lower several miles, the river maintains a nearly uniform fall of 11 feet per mile. Banks are low throughout, averaging about



MILLS RIVER BASIN

PLATE 22

six feet above low water from the mouth to above Foster Creek at Mile 3.8. From Foster Creek to the forks, banks average about ten feet above low water. When the banks are overtopped, a considerable part of the flow follows the bottoms on the left side of the river. Major floods overflow North Carolina Highway 280 to a depth sufficient to stop traffic, and secondary roads are flooded at many points in the upper basin.

Summary of Flood History

The results of the investigations of past floods in the Mills River Basin are summarized as follows:

1. The floods of August 1928 and August 30, 1940, are the largest that have occurred as a result of headwater during the past 65 years.

2. The flood of July 1916, due to backwater from the French Broad River, is the highest flood that has occurred over the lower mile and a half of the Mills River Basin. This flood was 7 feet higher than the August 1928 flood and 9-1/2 feet higher than the August 1940 floods in this location. In this reach, the height of floods is materially influenced by backwater.

3. The lower three miles of the river are characterized by wide fertile bottoms which are overflowed in even moderate floods, with heavy damages to crops.

4. The largest floods on Mills River have resulted from summer storms.

5. There are no encroachments on the Mills River flood plain which affect the height of floods.

6. The Mills River lands subject to flooding are practically all devoted to agricultural purposes and are almost entirely cleared and cultivated.

Flood Heights and Occurrences

Table 11 shows the crest stages which have been experienced on Mills River at the site of the present gaging station since 1876. None of the residents of the valley recall specifically any flood prior to June 1876. Although the flood information is not so complete as could be desired, it is believed that all of the large floods which have occurred since 1876 are included in the table.

The fourth column in the table gives the approximate elevation of the various floods at the mouth of Mills River. These elevations are definitely influenced by backwater from the French Broad River and show the marked effect of backwater on the height of floods in the lower end of the Mills River Valley. Investigations of floods along the French Broad River itself show the occurrence of large floods during years prior to 1876. Definite references to such floods on the Mills River have not been found.

TABLE 11

CREST STAGES OF DAMAGING FLOODS

AND

ESTIMATED FLOOD DAMAGES

WITH DEVELOPMENT AS IN 1941 CAUSED BY REPETITION OF PAST FLOODS

MILLS RIVER

Date of Flood		Crest Gage Height	Elevation	Approximate Elevation at Mouth of Mills River	Total Flood Damage	Damage Below Proposed Dam Site
June	1876	12	2100.4	2060	$ 16,500	$ 10,200
May	1901	11	2099.4	2057	8,500	4,850
February	1902	12	2100.4	2057	16,500	10,200
Jan. 22,	1906	10	2098.4	2058	4,200	2,600
Aug. 31,	1910	12	2100.4	2057	16,500	10,200
July 16,	1916	12.5	2100.9	2066	31,500	20,350
October	1918	10	2098.4	2055	4,200	2,600
July	1928	10	2098.4	2052	4,200	2,600
Aug. 16,	1928	13.5	2101.9	2059	30,900	17,500
Aug. 13,	1940	13.2	2101.6	2056.4	23,500	13,650
Aug. 30,	1940	13.6	2102.0	2056.4	28,500*	13,650
Total					$185,000	$108,400

Damage begins at a stage of 10 feet. The extent of flooding in the lower 1.5 miles of the river is largely dependent on the stage reached by the French Broad River. Due to backwater from French Broad River, floods of June 1876 and July 1916 were relatively higher for about a mile above the mouth of the river than farther upstream.

Flood heights prior to recorded data are estimated from high water marks and other available data.

* Estimate based on flood of same extent as August 30, 1940, independent of damage caused by preceding flood such as occurred on August 13, 1940.

Magnitude of Past Floods

Data are not available from which to estimate the flood volumes and peak rates of flow for all floods, but they are sufficient to do so for the floods of July 1916, August 16, 1928, and the two floods of August 1940.

Table 12 gives information for these floods together with other pertinent rainfall and runoff data.

TABLE 12

FLOOD FLOW AND RUNOFF

MILLS RIVER BASIN

(Drainage Area 66.7 Square Miles)

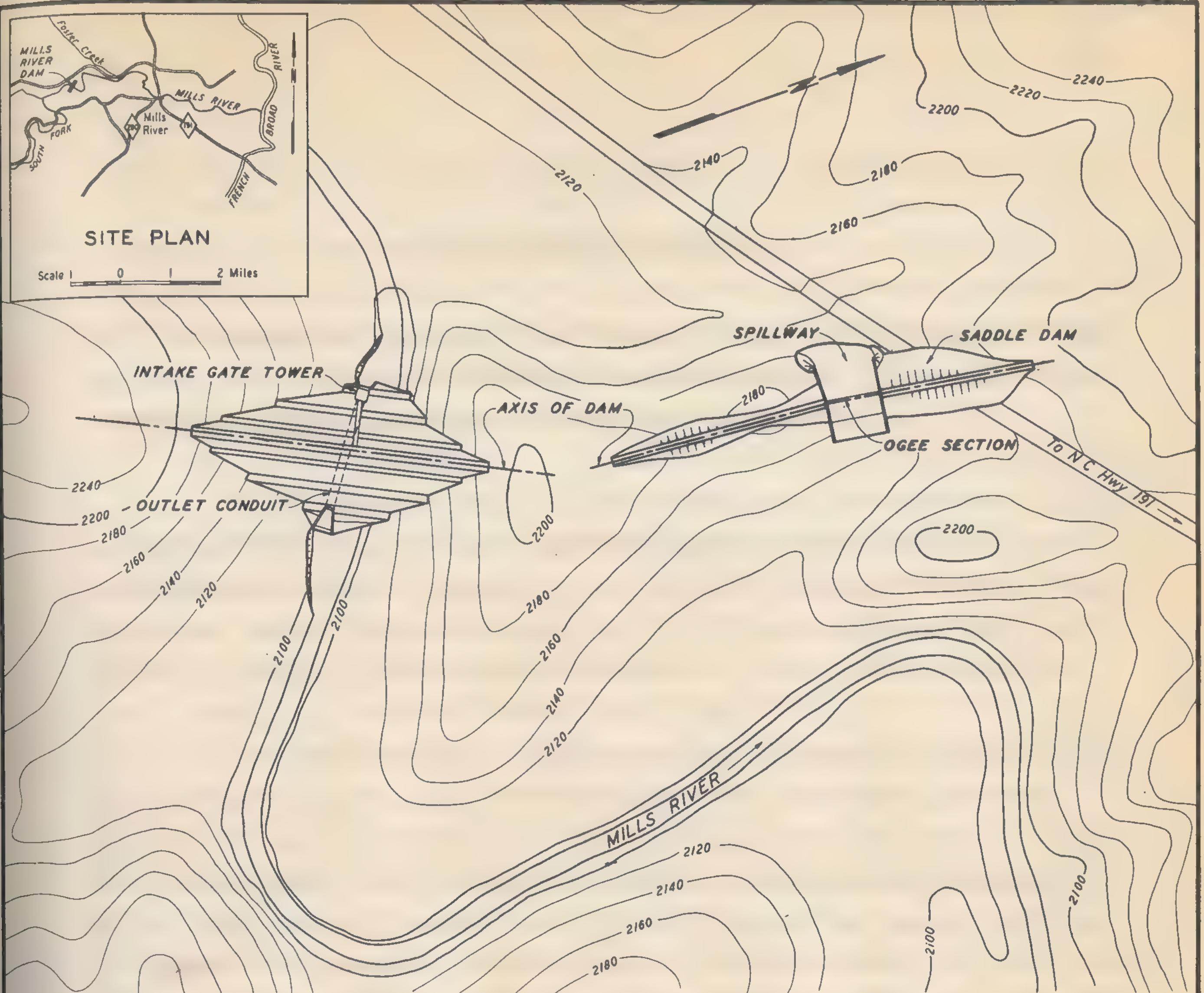
Date	Average Rainfall	Gage Height	Peak Discharge Amount	Peak Discharge Per Sq.Mi.	Surface Runoff		Runoff to Rainfall
	Inches	Feet	c.f.s.	c.f.s.	Ac.Ft.	In.	Percent
July 1916	7.0	12.58	8,400	126	8,400	2.4	34
Aug. 16, 1928	-	13.5	9,700	145	-	-	-
Aug. 13, 1940	11.5	13.15	9,200	138	11,000	3.1	27
Aug. 30, 1940	8.5	13.62	9,850	148	9,600	2.7	32

Flood Damages

Table 11 gives estimated flood damages in the Mills River Basin for known floods of the past, assuming these were to recur with development as it was in 1941. Damages are estimated for the stream as a whole and for the part downstream from the proposed reservoir. It is probable that, due to the lack of flood information during the earlier years, minor floods have occurred of which there is no evidence but which would cause damages and increase the total shown in the table. Appendix B contains further information on damages.

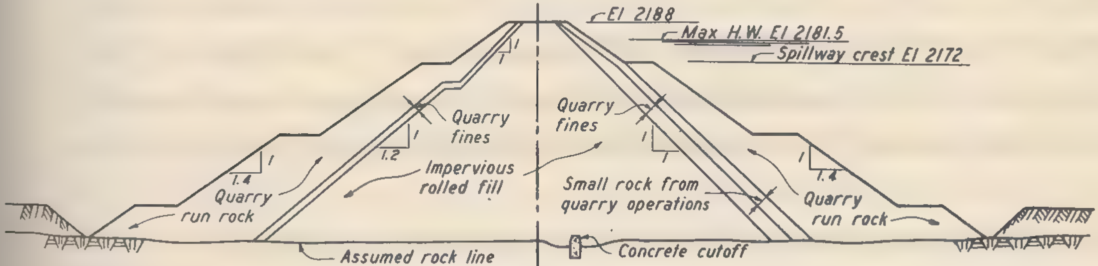
Damages from Repetition of Flood of July 16, 1916

This flood was particularly heavy on the lower part of the river where backwater from the main French Broad extended into the Mills River



PLAN

Scale 0 200 400 Feet



SECTION

Scale 0 40 80 Feet

NOTES:

Design shown is preliminary and subject to change when more detailed information on the site and materials available for construction is obtained prior to construction.

Site topography from TVA special topographic survey.

Low water at El 2098. Maximum height of dam, 90 feet.

135 foot wide spillway.

Single outlet conduit, gate controlled.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

GENERAL PLAN
MILLS RIVER DAM

4. DAVIDSON RIVER

The Flood Situation

Control of Davidson River floods as a part of the Regional Plan is proposed to be obtained by a storage reservoir near the mouth of the river. Plate 24 is a map of the basin showing the reservoir.

Davidson River enters the French Broad from the west about 44 miles above Asheville. Its drainage area of 47 square miles is for the most part mountainous and wooded. Less than one percent is under cultivation. Almost the entire basin is within the boundary of the Pisgah National Forest and bounded by mountain ranges varying from 3500 to 6000 feet in elevation.

With the exception of the Ecusta Paper Corporation plant, the Carr Lumber Company, small commercial developments and surrounding low-cost housing area in the town of Pisgah Forest, houses and buildings are located above high water. Flood damage is ordinarily limited to the overflow of bottom lands near the mouth of the river and the washing away of small bridges and flooding of roads in the forest area. Floods on this river are a menace to the agricultural lands in the French Broad Valley and also to the huge industrial plant of the Ecusta Paper Corporation on the right bank of the river just below State Highway No. 280. The Ecusta plant is surrounded by a levee which affords protection against moderate floods but not against the extreme floods which may be expected from this watershed. Highways are subject to only minor flood damage. The Toxaway Branch of the Southern Railway which crosses the river at Pisgah Forest suffers little damage from floods other than the washing of fills and overflow of low sections of track.

Lumbering became the main occupation of many of the valley's inhabitants after practically the entire watershed was acquired by George W. Vanderbilt. In 1914, extensive lumbering was begun on the Vanderbilt holdings by the Carr Lumber Company and Davidson River was one of the first sections cut over. The Vanderbilt holdings were purchased later by the Federal Government to become the Pisgah National Forest. The Davidson River portion of the forest now has a nearly complete cover of good second-growth timber.

Few families have lived above the mouth of Avery Creek probably because of the lack of tillable bottom land. In 1941, only four families occupied the bottom land between Avery Creek and the North Carolina Highway 280 bridge. The flat land below the North Carolina Highway 280 bridge, outside the National Forest preserve, is occupied by houses of employees of Ecusta Paper Corporation and Carr Lumber Company.

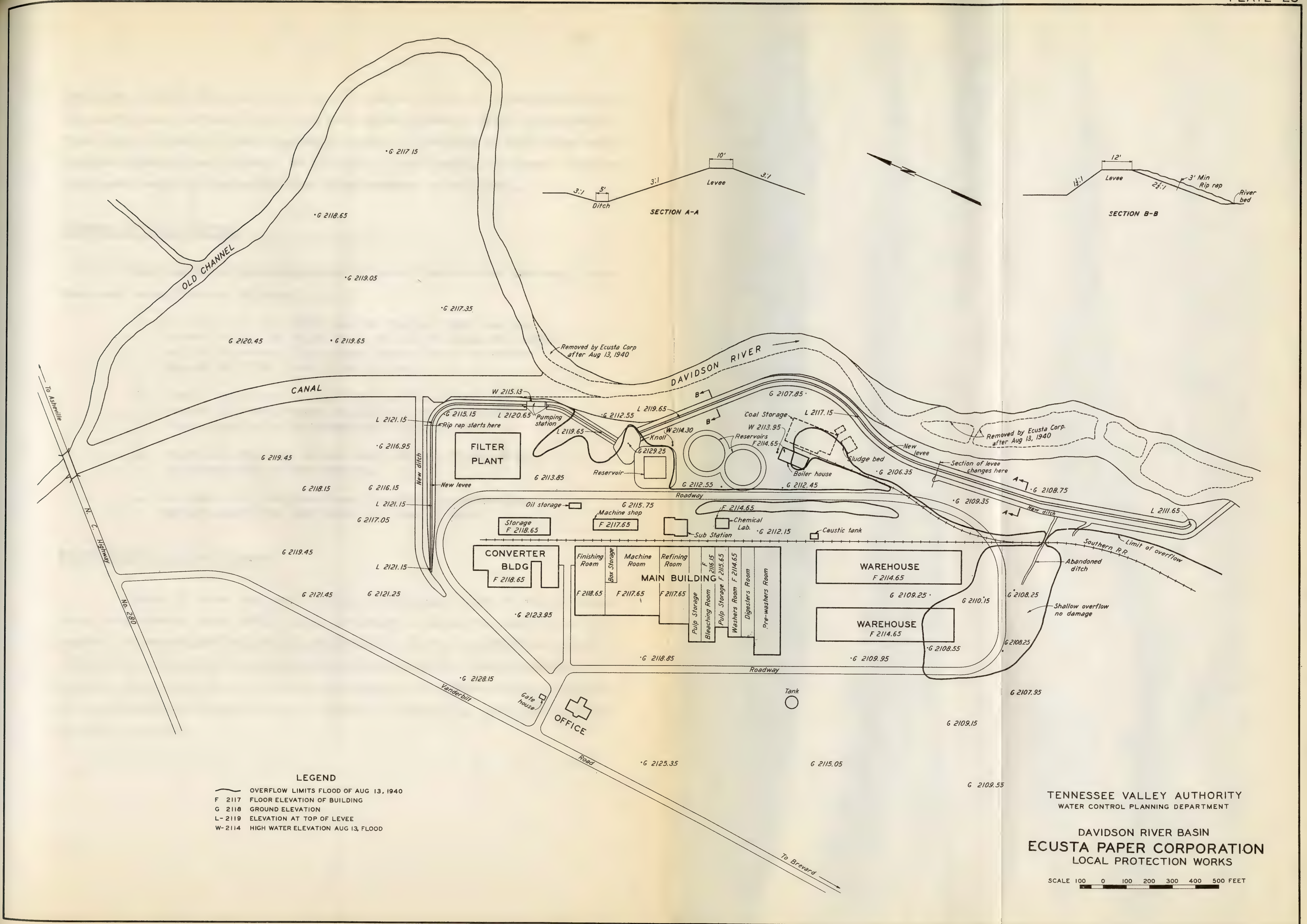
The River and Its Valley

Davidson River has comparatively steep slopes for the lower two miles of its course, being 13-1/2 feet per mile. Above the mouth of Avery Creek, the slope increases to 30 feet per mile. Overflow widths are narrow except for the lower two miles. Floods break over the left bank near Mile 1.5 and overflow the flat lands on that side of the river. The local protection works of the Ecusta Paper Corporation plant restrict the overflow on the right bank in the vicinity of Mile 1.0.

Ecusta Paper Corporation

The Ecusta Paper Corporation is located on the right bank of Davidson River between North Carolina State Highway 280 and the mouth of the river. Plate 25 shows the general layout of the plant and the local protection works which have been constructed by the corporation. Although the floods of August 13 and 30, 1940, caused only minor damages to the paper corporation, totaling about $14,000, they served to call attention to the possibility of serious flood damages. Previous to 1940, a cutoff canal was excavated across a loop in the river beginning at approximately Mile 2 and ending opposite the upper end of the corporation's plant. Additional works were constructed after the 1940 floods. These included the construction of about 4000 feet of levee along the right bank of Davidson River around the paper plant and the widening and clearing of about half a mile of the river channel from the downstream end of the canal previously constructed to the lower end of the company's property. The levee is built to a grade line approximately 3 to 5 feet above the 1916, 1928, and mid August 1940 flood crests and affords protection against greater floods than any of those which


KEY MAP
TENN
N CAR
ASHEVILLE
MARSHALL
NEWPORT
FRENCH
BROAD
RIVER
Pigeon R
Hominy Cr
Mills
Davidson R
Little R
Mud Cr
LEGEND
GAGING STATION
PISGAH NATIONAL FOREST BOUNDARY
N
Pounding Mill Branch
Cherry Cove Branch
Log Hollow Branch
Big Bear Pen Branch
Lookingglass Creek
Henry Branch
Avery Creek
284
Shuck Ridge Creek
Daniel Ridge Creek
Right Fork
Cove Creek
Rockhouse Creek
DAVIDSON RIVER
Laurel Fork
Long Branch
Grogan Creek
Horse Cove
Shutin Branch
Joel Branch
South Prong
North Prong
Turkey Creek
Blacksnake Branch
Thrift Cove Branch
Silver Creek
PROPOSED RESERVOIR
To Asheville
280
Ecusta Paper Corporation
To Brevard
Carr Lumber Co
Southern
Pisgah Forest
R R
64
FRENCH BROAD RIVER
DAVIDSON RIVER BASIN
Scale 1 0 1 Miles


SECTION A-A
10'
Levee
3:1
5'
Ditch
SECTION B-B
12'
3' Min Rip rap
River bed
OLD CHANNEL
CANAL
DAVIDSON RIVER
Removed by Ecusta Corp after Aug 13, 1940
To Asheville
N. C. Highway No 280
FILTER PLANT
New ditch
New levee
Rip rap starts here
Pumping station
Knoll
Reservoir
Reservoirs
Coal Storage
Boiler house
Sludge bed
Section of levee changes here
New ditch
Southern R.R.
Limit of overflow
Abandoned ditch
Shallow overflow no damage
Oil storage
Machine shop
Storage F 2118.65
Sub Station
Chemical Lab.
Caustic tank
CONVERTER BLDG F 2118.65
MAIN BUILDING
Finishing Room
Box Storage
Machine Room
Refining Room
Pulp Storage
Bleaching Room
Washers Room
Digesters Room
Pre-washers Room
WAREHOUSE F 2114.65
WAREHOUSE F 2114.65
Roadway
Tank
Gate house
OFFICE
Vanderbilt Road
To Brevard
LEGEND
OVERFLOW LIMITS FLOOD OF AUG 13, 1940
F 2117 FLOOR ELEVATION OF BUILDING
G 2118 GROUND ELEVATION
L-2119 ELEVATION AT TOP OF LEVEE
W-2114 HIGH WATER ELEVATION AUG 13, FLOOD
TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT
DAVIDSON RIVER BASIN
ECUSTA PAPER CORPORATION
LOCAL PROTECTION WORKS
SCALE 100 0 100 200 300 400 500 FEET

are known to have occurred in the past. However, there is a possibility that the mountainous Davidson River watershed might produce a flood approximately five times as great in peak discharge as that of the 1928 or 1876 flood which are the highest floods known. Should such a flood occur, the Ecusta Corporation levee would be overtopped with large damages to the plant.

Summary of Flood History

The results of investigations of past floods in the Davidson River Basin are summarized as follows:

1. The flood of June 1876 was the highest that has occurred during the past 65 years except along the lower mile of Davidson River where French Broad backwater caused the 1916 flood to be higher.

2. Floods occurring in July 1916, October 1918, and August 1928 were nearly as high as the June 1876 flood, particularly downstream from Mile 3.

3. Backwater from the French Broad River affects only the lower mile of the stream.

4. The width of overflow along the river is generally narrow except for the lower mile and a half.

Flood Heights and Occurrences

Table 13 shows the crest stages of damaging floods on the Davidson River near Brevard since 1876. Flood information during the early years is meager. No references either in periodicals or in the recollection of old residents were located for any flood prior to June 1876. It is probable, however, that during some of the early floods on the French Broad and others of its tributaries of which there is record at Asheville, the Davidson River was also in flood.

TABLE 13

CREST STAGES OF DAMAGING FLOODS

AND

ESTIMATED FLOOD DAMAGES

WITH DEVELOPMENT AS IN 1941 CAUSED BY REPETITION OF PAST FLOODS

DAVIDSON RIVER

Date of Flood		Crest Gage Height*	Elevation	Total Flood Damage	Damage Below Proposed Dam Site
June	1876	11.9	2127.0	$ 8,900	$ 7,500
July 16,	1916	10.3	2125.4	15,200	14,850
October	1918	10.9	2126.0	2,100	1,550
August 15,	1928	11.80	2126.9	8,900	7,500
October 22,	1932	10.04	2125.2	1,800	1,450
January 8,	1935	8.80	2123.9	150	150
October 18,	1938	7.85	2123.0	200	200
August 13,	1940	9.22	2124.2	1,700[a]	1,650
August 30,	1940	7.68	2122.8	200[b]	200
	Total			$39,150	$35,050

* Gage heights are for the stream gage at Mile 2 above the mouth of the river. Damaging stage at the gage is about 11 feet. Below Mile 1.5, overflow and damage occur at stages above about 8 feet.

a Actual loss was $15,700

b Actual loss was only $100 due to crops being damaged by previous flood.

Magnitude of Past Floods

Table 14 gives information for those floods for which data are available to estimate flood volumes and peak rates of flow.

TABLE 14

FLOOD FLOW AND RUNOFF

DAVIDSON RIVER BASIN

(Drainage Area 40.4 Square Miles)

Date		Average Rainfall	Gage Height	Peak Discharge Amount	Peak Discharge Per Sq.Mi.	Runoff		Runoff to Rainfall
		Inches	Feet	c.f.s.	c.f.s.	Ac.Ft.	In.	Percent
June	1876	-	11.9	-	-	-	-	-
July	1916	8.7	10.3*	7,700	190	8,600	4.0	46
October	1918	-	10.9*	-	-	-	-	-
August	1928	-	11.8	8,400	208	-	-	-
Aug. 13,	1940	11.0	9.22	6,100	151	5,800	2.7	24
Aug. 30,	1940	8.0	7.68	4,300	107	4,000	1.9	23

* Estimated from best available data.

Flood Damages

Table 13 gives estimated flood damages in the Davidson River Basin assuming that known floods of the past were to recur with conditions as they were in 1941. Damages are estimated for the stream as a whole and for the part downstream from the proposed storage reservoir. The Davidson River Basin has never been very thickly populated and information on past floods is very deficient. Undoubtedly there were floods during the period from 1876 to 1916 of which no trace now exists. If such floods were to be added to the table, the amount of damage would be increased.

The table of damages also does not give a complete picture of the damages that may be suffered from extreme floods. A flood of sufficient magnitude, to either breach or overtop the levee around the Ecusta Paper

Corporation plant, would cause tremendous damages to that plant. Appendix B contains further information on damages.

Flood Protection Plan

The control of floods on Davidson River may best be accomplished by a detention basin reservoir. There is an excellent location for such a reservoir on the lower part of this stream which would provide control of practically the entire drainage area.

Davidson River Reservoir

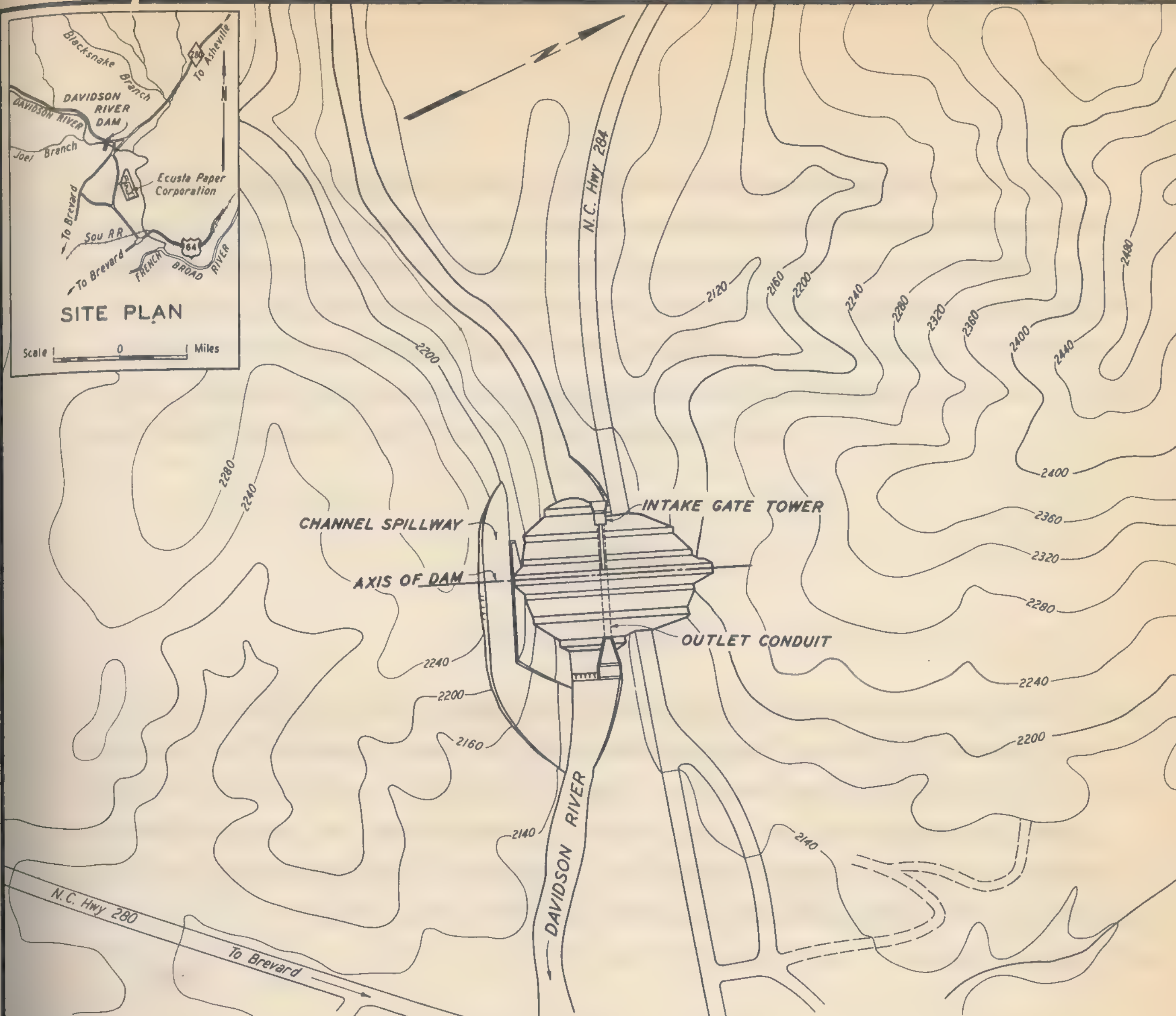
The site for the dam for this reservoir is just upstream from the State Highway 280 bridge and about two miles from the mouth of the river. At this location the banks on each side are very steep and the river valley is narrow. Upstream from the dam site the valley widens out so that storage space becomes available. The location and extent of the reservoir are shown on Plate 24. Plate 26 is a general plan of the dam.

The dam is planned to be an earth and rock fill type of structure. The reservoir above the dam will have capacity to store water amounting to six inches from the watershed of 41 miles upstream with the water at the level of the spillway. There would be an outlet conduit through the dam which will have a maximum capacity of 4700 cubic feet per second.

State Highway 284 extends up the Davidson River Valley to Avery Creek and then follows that stream. A branch road continues on up Davidson River. It is contemplated that Highway 284 would be relocated in the vicinity of the dam site but upstream through the reservoir the roads will not be interfered with sufficiently to justify relocation.

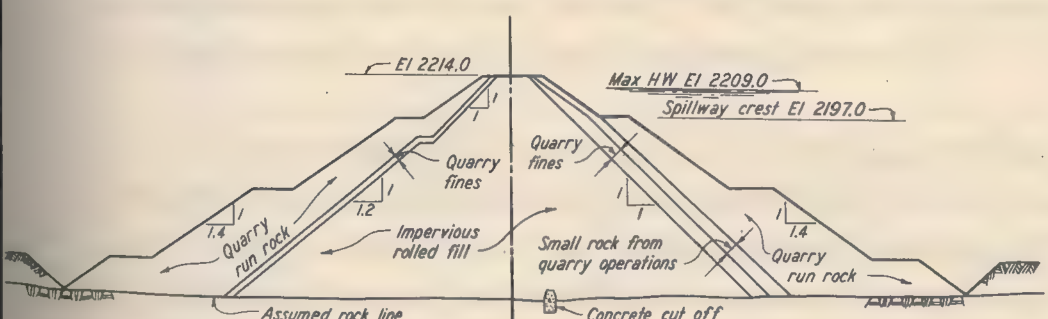
Protection Provided

The lands downstream from the dam would receive agricultural flood protection of the character which has been described previously. This includes



PLAN

Scale 0 200 400 Feet



SECTION

Scale 0 40 80 Feet

NOTES:

Design shown is preliminary and subject to change when more detailed information on the site and materials available for construction is obtained prior to construction.

Site topography taken from advance sheets of USGS-TVA topographic maps.

Low water at El 2122. Maximum height of dam, 92 feet.

68 foot wide open channel spillway on right bank.

The single outlet conduit is gate controlled.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

GENERAL PLAN
DAVIDSON RIVER DAM

the lands along the lower part of Davidson River and also the lands in the valley of the main French Broad River downstream from Davidson River. The Ecusta Paper Corporation would receive the protection which it needs in addition to its present levee in order to prevent the plant being overflowed and damaged during great floods which may occur on the Davidson River watershed. Asheville and other down river locations would benefit from the Davidson River Reservoir as a part of the Regional Plan.

5. MUD CREEK

The Flood Situation

Mud Creek is an important tributary of the French Broad River which empties into the main river 20 miles upstream from Asheville, between Cane Creek and Mills River. The lands along the French Broad in this part of the river are among the most fertile in the valley. The flood plain in this section is wide and well developed. It is particularly important, therefore, to control the flood runoff from Mud Creek in order to protect these valuable lands as well as to reduce floods at Asheville and other locations downstream.

Under the Regional Plan, it is proposed to construct a storage reservoir near the mouth of Mud Creek which will control practically the entire drainage area of the stream. The location and extent of the reservoir is shown on the map of the Mud Creek Basin, Plate 27.

Mud Creek has a drainage area of 113 square miles. The lands along the lower part of the creek are about elevation 2000 or less. The higher lands on the eastern rim of the watershed reach elevation of about 3000. The stream is unusual for this region because of the flat slope of the creek and its valley.

The town of Hendersonville is in the watershed and Mud Creek flows along its eastern boundary.

Federal Highway Numbers 24, 64, and 176 lead from Hendersonville to the surrounding region and all of these cross Mud Creek. The main line of the Southern Railway, Asheville to Spartanburg Division, extends through the basin following the general line of the creek below Hendersonville.

Floods overflow the bottoms along the creek causing considerable damage to crops. Roads and bridges are also damaged and severe floods damage the railway. Farm buildings are located generally above high water. The city of Hendersonville is above flood damage but suffers from inconvenience when highways to the north and east are overflowed.

The Creek and Its Valley

Mud Creek has the flattest channed gradient to any important stream in the Upper French Broad watershed. For the lower ten miles, the slope of the channel is only 4 feet per mile. The banks of the stream are low, averaging about 6 feet above low water, and in the three mile reach from Balfour to Hendersonville are only 3-1/2 feet above low water. The flat bottom lands in the creek valley are extensively cultivated. However, drainage of the bottom lands is imperfect and limits cultivation to less than half of the available bottom lands. Some drainage work has been done in recent years in an effort to improve natural conditions.

Summary of Flood History

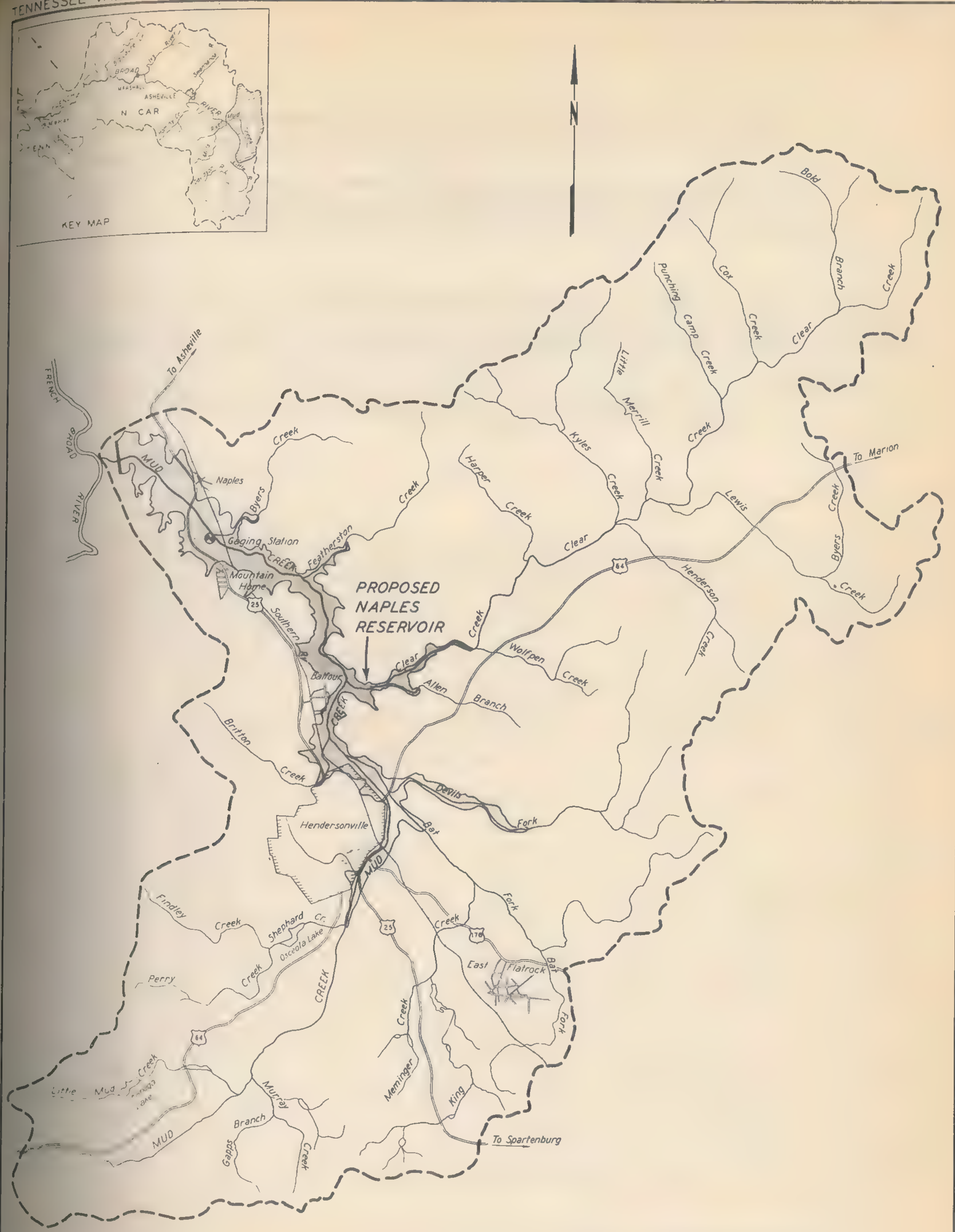
The results of the investigations of past floods in the Mud Creek Basin are summarized as follows:

1. The flood of July 16, 1916, far surpasses any other in the history of the basin.

2. The next largest floods are those of June 1876, August 1910, and August 1928.

3. The largest floods on Mud Creek have resulted from summer storms.

4. Extensive overflow occurs along the creek during each important flood, the width of overflow varying from a quarter to a half mile.



MUD CREEK BASIN

Scale 1 0 1 2 Miles

LEGEND
GAGING STATION

5. Backwater from the French Broad River affects the Mud Creek Valley for a distance of about 5 miles.

6. Principal damage from floods is to crops. During major floods, U. S. Highways 25, 64, and 176 and the main line tracks of the Southern Railway are overflowed.

Table 15 shows the elevations reached by damaging floods on Mud Creek at the site of the present stream gage near Naples. Little information can be obtained on floods prior to 1916. That flood so far outstripped previous floods that the latter have been practically forgotten.

TABLE 15

CREST STAGES OF DAMAGING FLOODS

AND

ESTIMATED FLOOD DAMAGES

WITH DEVELOPMENT AS IN 1941 CAUSED BY REPETITION OF PAST FLOODS

MUD CREEK

Date of Flood	Crest Gage Height*	Elevation	Total Flood Damage	Damages Above Clear Creek	Damages Below Clear Creek
June 1876	15.0	2062.5	$50,500	$15,300	$35,200
May 1901	13.0	2060.5	26,500	8,200	18,300
December 1901	12.0	2059.5	19,700	6,600	13,100
February 1902	12.0	2059.5	19,700	6,600	13,100
January 22, 1906	10.0	2057.5	13,100	3,300	9,800
July 1910	10.0	2057.5	13,100	3,300	9,800
August 1910	15.5	2063.0	50,500	15,300	35,200
July 10, 1916	15.0	2062.5	50,500	15,300	35,200
July 16, 1916	21.5	2069.0	122,000	38,200	83,800
August 16, 1928	14.9	2062.4	50,500	15,300	35,200
October 16, 1932	13.5	2061.0	26,500	8,200	18,300
April 6, 1936	9.0	2056.5	5,750	1,250	4,500
August 19, 1939	8.53	2056.0	800	200	600
August 13, 1940	13.07	2060.6	26,500	8,200	18,300
August 30, 1940	11.00	2058.5	15,700	5,350	10,350
Total - - - - - - - - - - - - -			$491,350	$150,600	$340,750

* At Naples stream gage.

Bankfull stage on the left bank is 9 feet and on the right bank 8 feet. Overflow occurs in some small areas upstream at less than 8 feet.

Magnitude of Past Floods

Table 16 gives available rainfall and runoff information for the floods of July 1916, August 1928, and August 1940.

TABLE 16

FLOOD FLOW AND RUNOFF

MUD CREEK BASIN

(Drainage Area 109 Square Miles)

Date	Rainfall	Gage Height	Peak Discharge Amount	Peak Discharge Sq. Mi.	Runoff		Runoff to Rainfall
	Inches	Feet	c.f.s.	c.f.s.	Ac.Ft.	In.	Percent
July 1916	15.9	21.5	40,000	366	73,500	12.6	79
Aug. 1928	-	14.9	17,000	156	-	-	-
Aug. 13, 1940	8.8	13.07	10,800	99	18,500	3.2	36
Aug. 30, 1940	6.8	10.99	4,800	44	12,300	2.2	32

Flood Damages

Table 15 gives the estimated flood damages in the Mud Creek Basin for known floods of the past, assuming that these were to recur with improvements as they were in 1941. Damages are separated for the property above the mouth of Clear Creek and below Clear Creek. It is probable that there were some floods in the period from 1876 to 1901, of which no trace has been found. The addition of such floods to the table would increase the total amount of damages. Damages in the Mud Creek Basin would not be decreased by the Regional Plan for flood protection as this does not provide protection for these lands. Appendix B contains further information on damages.

Damages for Repetition of July 16, 1916, Flood

This flood exceeds all others in the Mud Creek Basin and caused large damages to agricultural crops and improvements, to highways and to the

Southern Railway. Several recreational dams washed out. Should such a flood recur with conditions as they were in 1941, it is estimated that damages would total $122,000 divided according to type as follows:

Agricultural	$54,500
Domestic	7,500
Highways	27,000
Railroad	32,000
Utilities	1,000

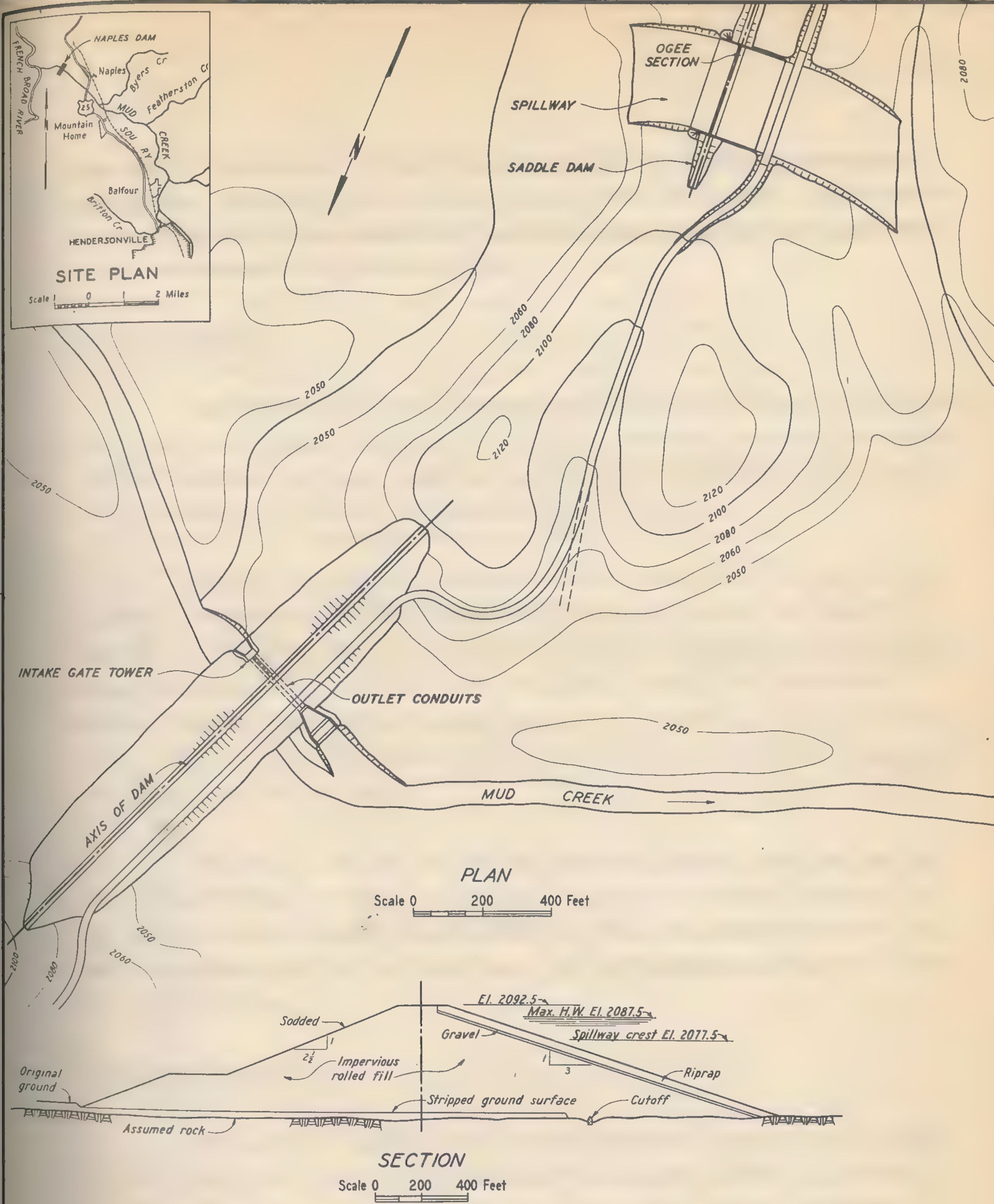
Damages from August 1940 Floods

The mid-August flood was not exceptionally high in the Mud Creek Basin, being the third highest since 1916. This resulted in damages of $26,500 largely to crops and agricultural improvements. The late August flood was from one to two feet lower than the mid-August flood and only minor additional losses resulted. Some of the lands in the Mud Creek Valley are used for truck crops and losses per acre for such crops were large during the mid-August flood, ranging from $100 for general truck crops up to $260 per acre for lima beans. Corn and hay crops which constituted the greater part of the acreage damaged averaged about $20 per acre loss.

Flood Protection Plan

Flood control for the valley lands along Mud Creek itself is not feasible. The width of the valley is insufficient to justify levees or enlargement of the channel to the necessary size to carry big floods. Unfortunately, the topography of the watershed is such that there are no satisfactory sites for storage reservoirs upstream from Hendersonville which could fit into the Regional Plan and at the same time protect the Mud Creek valley lands. Sites along the middle reaches of the stream would overflow Hendersonville to an extent greater than natural overflow.

However, the contribution of Mud Creek to the floods in the French Broad valley and along the Asheville water front is important and it is essential that floods on Mud Creek be controlled as a part of the Regional



NOTES:

Design shown is preliminary and subject to change when more detailed information on the site and materials available for construction is obtained prior to construction.

Site topography taken from advance sheets of USGS-T.V.A. topographic maps.

Low water Elevation 2044. Maximum height of dam, 48.5 feet.

Spillway, 275 feet wide.

Twin outlet conduits, gate controlled.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

GENERAL PLAN
NAPLES DAM
MUD CREEK

Plan for the protection of the French Broad Valley, Asheville, and points downstream. There is a site near the mouth of the creek for a dam to create a storage basin for the control of Mud Creek floods and it is proposed that a dam be constructed at this location.

Naples Reservoir

The site for the dam to create this reservoir is about a mile above where Mud Creek empties into the French Broad. The town of Naples is nearby and the reservoir has been named for that place. Plate 27 shows the extent of the reservoir. Plate 28 is a general plan of the dam.

The dam is planned to be an earth fill structure. Because of the location and elevation of Hendersonville, it is not possible to obtain as much storage from the Mud Creek watershed as from other basins in the Upper French Broad region. With the water at spillway level, the capacity of Naples Reservoir is 4 inches from the watershed of 113 square miles upstream. There would be an outlet conduit through the dam which would have capacity of 9000 cubic feet per second.

Where U. S. Highway 25 and the Southern Railway cross the valley near the settlement of Mountain Home, it is proposed to raise these so that they will be above ordinary flood overflow. Other highways which cross the Naples Reservoir will not be interfered with sufficiently to warrent adjustment or relocation.

Protection Provided

Acting as an integral part of the Regional Plan for flood control, the Naples Reservoir will aid in reducing flood heights which is essential for the protection of the French Broad Valley and the city of Asheville. As previously stated, the reservoir would afford no protection to the Mud Creek Valley. Ultimately, the development of this region may reach the state where headwater reservoirs or other works may be justified for the flood protection of the Mud Creek lands.

6. LITTLE RIVER

The Flood Situation

As a part of the Regional Plan, a storage reservoir is proposed on Little River, one of the upper tributaries which empties into the French Broad 40 miles upstream from Asheville and four miles downstream from Davidson River. Plate 29 is a map of the basin showing the reservoir.

The drainage area of Little River is 60 square miles. Elevations in the watershed range from about 2000 near the mouth of the river to 3000 on the eastern rim which separates the French Broad from the Atlantic drainage. The watershed is covered for the most part with burned over second-growth forest which is probably the poorest forest cover on the entire Upper French Broad watershed. The lower three miles of the river are bordered by a fairly wide flat valley which is cultivated for agricultural crops.

The Cascade Dam of the Little River Power Company is located on Little River about 4 miles above the mouth. The river valley along the reach in which the dam is located has a steep fall and the stream flows in a narrow valley. Along the lower reaches of the river where the valley is wider, the slope of the river is flatter.

No detailed investigation has been made of past floods on Little River. No stream gaging station has been maintained on the stream to provide records of floods.

The July 1916 was the largest flood known on Little River. Other large floods were those of August 1928 and August 1940. The heights and magnitudes of these and other floods have not been investigated but all of these were of such a height as to have overflowed the valley lands along Lower Little River.

Flood Damages

Flood damages on Little River are largely agricultural. Extimates of such damages are included in the table for the Upper French Broad Valley.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

LITTLE RIVER BASIN

SCALE 1 0 1 2 MILES

In mid-August 1940, the total loss to farm crops along Little River amounted to about $3600. Most of the valley was in corn at that time with small acreages in truck and other crops. Other losses were minor. Large floods would cause damages on Little River approximating those in 1940.

Flood Protection Plan

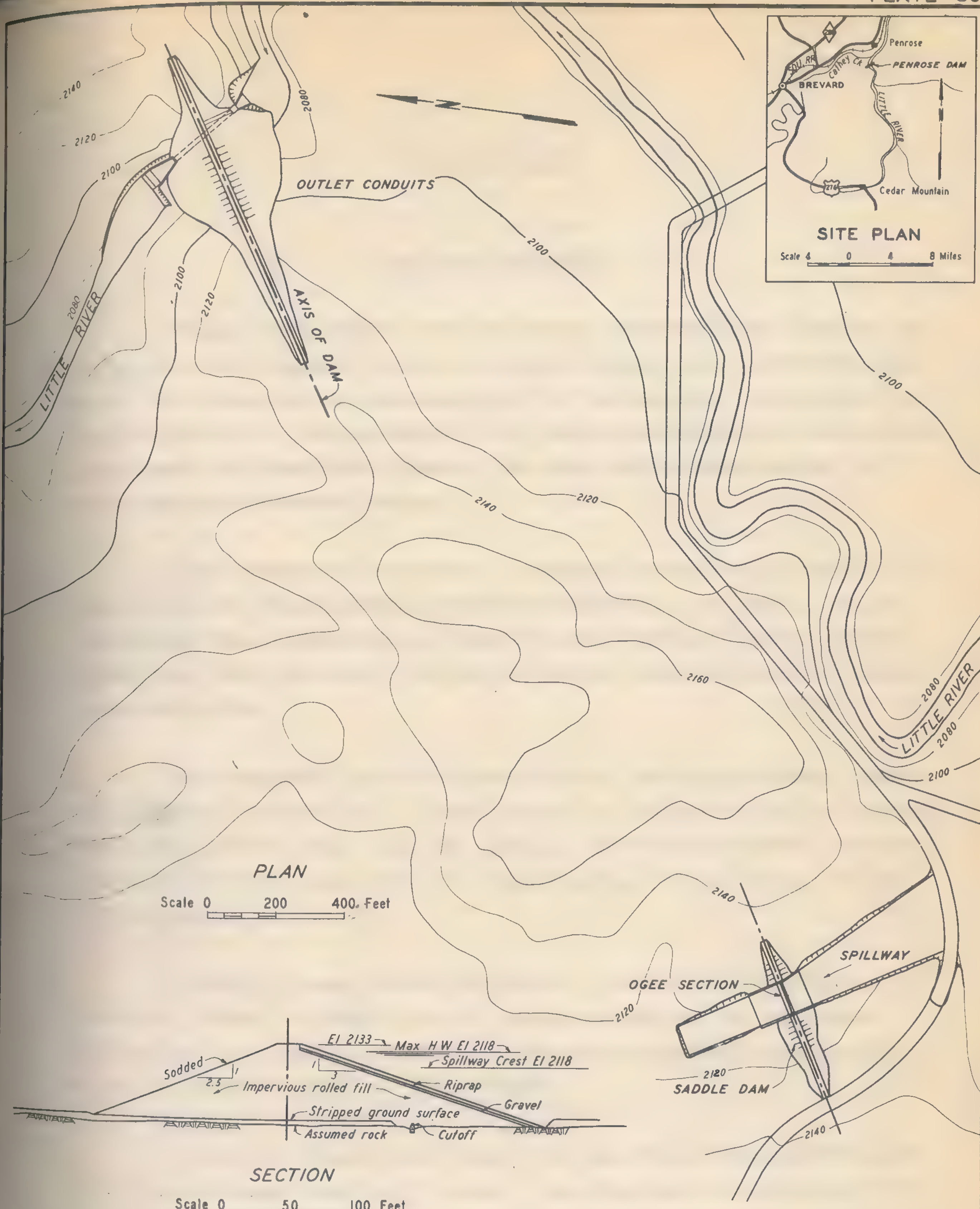
Control of Little River floods is necessary as a part of the Regional Plan. It does not appear to be feasible to protect the lands along the lower part of Little River as this reach offers the only suitable location for a storage reservoir to control Little River. There are no satisfactory reservoir sites farther upstream which would have the required capacity.

Penrose Reservoir

The dam to create this reservoir is located across the Little River valley just above the mouth of the stream opposite the small settlement of Penrose for which the proposed reservoir is named. Plate 30 is a general plan of the dam. The dam is planned to be an earth fill structure. With the water at spillway level in the reservoir the capacity to store water amounts to 6 inches from the watershed. The gate controlled outlet conduit through the dam would have a capacity of 5000 cubic feet per second.

Protection Provided

The Penrose Reservoir on Little River would function as an integral part of the Regional Plan to reduce flood heights on the French Broad River. The reservoir would not protect any of the lands along Little River.



NOTES:

Design shown is preliminary and subject to change when more detailed information on the site and materials available for construction is obtained prior to construction.

Site topography taken from advance sheets of USGS-TVA topographic maps.

Low water at El 2075. Maximum height of dam, 58 feet.

95 foot wide ogee section spillway.

Twin outlet conduits, gate controlled.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

GENERAL PLAN
PENROSE DAM
LITTLE RIVER

The Creek and Its Valley

From the mouth of the creek upstream for five miles the fall of the creek averages about 9-1/2 feet per mile. The banks are about 15 feet in average height and the adjoining bottom lands are narrow and bordered by high rolling hills. Houses in this reach are well above high water and flood damages are not important.

The next three miles of the creek which extend up to the plant of the American Enka Corporation have banks averaging about 12 feet high. The slope of the channel is somewhat flatter but still averages 8-1/3 feet per mile. There is a wide flat on the right bank at the Enka plant site, and on the left bank three-quarters of a mile above Enka is another flat, both of which are subject to overflow in major rises except for the protection afforded by the Enka levees. From Enka on upstream to Candler at Mile 11 the slope of the channel is about 13-1/2 feet per mile and the banks are about ten feet high.

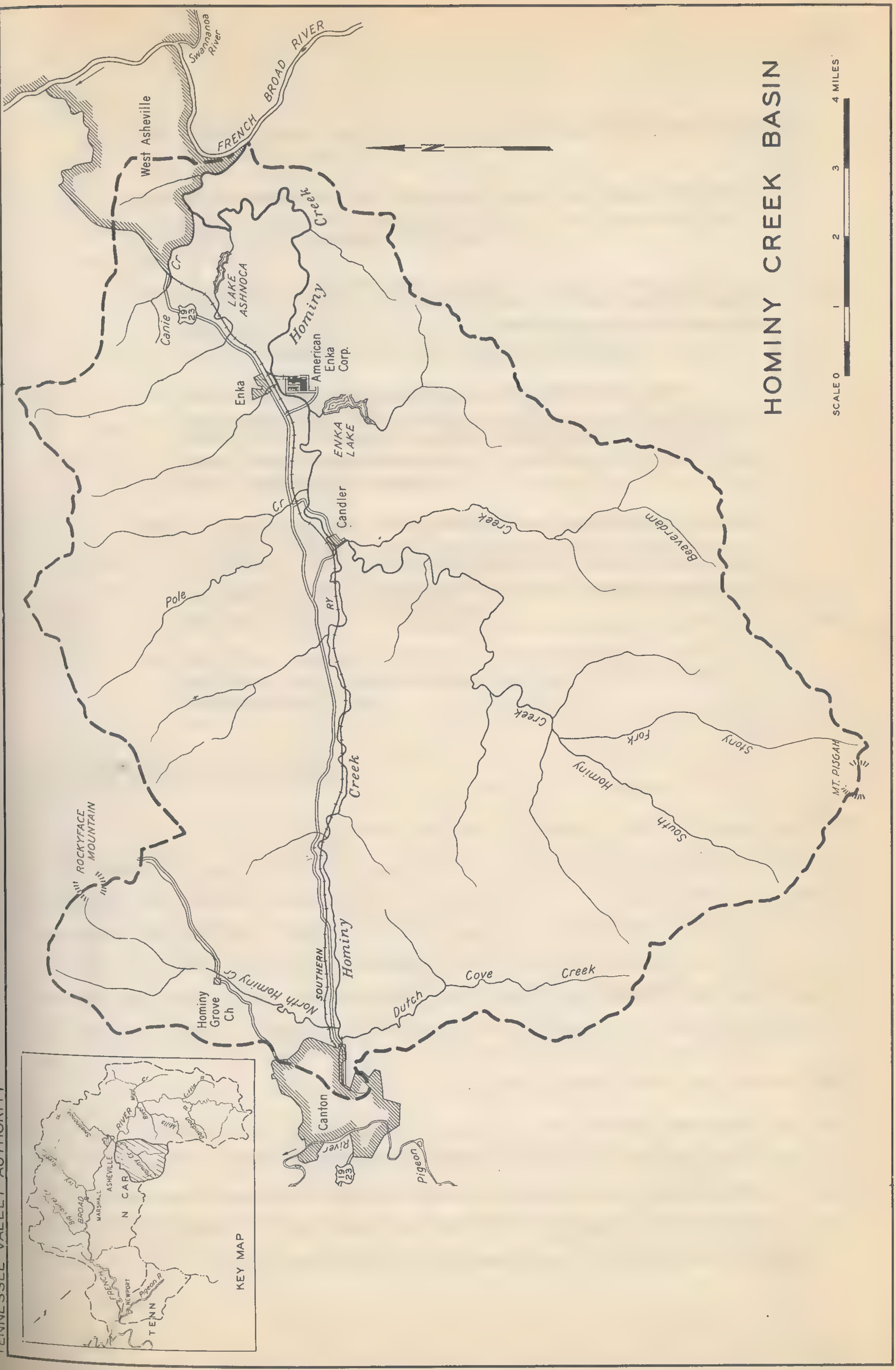
The high water of July 1916 at the mouth of the creek in the French Broad River backed water only over the lower mile of the creek causing practically no flood damage. Consequently, any flood damage on the creek will be caused by headwater and not by backwater. Near the lower end of the creek the bankfull capacity of the stream is about 2000 cubic feet per second. This is only a small part of the peak flood flow which occurred in late August 1940 which is estimated at 12,800 cubic feet per second.

Summary of Flood History

The results of the investigations of past floods in the Hominy Creek basin are summarized as follows:

1. The flood of August 30, 1940, is the greatest that has occurred during the past 100 years, and there are indications that this is the largest that has occurred during the 150 or more years since the earliest settlers came into the valley.

WATER CONTROL PLANNING DEPARTMENT



TENNESSEE VALLEY AUTHORITY

2. Large floods also occurred on February 28, 1902, August 1910, and June 1876.

3. The largest floods on Hominy Creek are likely to be caused by summer storms, either of the hurricane or convective thunderstorm type.

4. Backwater from the French Broad River during high floods extends only about a mile up the Hominy Creek Valley and creates no flood problem; the flood problems on Hominy Creek are entirely due to headwater.

5. Prior to the construction of the American Enka Corporation plant about ten years ago, only comparatively minor damage resulted from floods on Hominy Creek but large floods which overflow this plant now cause tremendous damages.

6. The American Enka Corporation has constructed, since the 1940 floods, local protection works which give protection against floods slightly greater than that of 1940 but this is insufficient to protect against maximum floods that may occur.

7. The flood plain at Enka has been materially constricted by the construction of the American Enka Corporation plant.

Flood Heights and Occurrences

Table 17 shows the crest stages of damaging floods which have been experienced on Hominy Creek at Enka since 1873. These are taken from gage readings, high water marks found in the field, or estimated from information contained in newspaper articles which could be definitely tied in to some feature of known elevation. Although the flood information on this creek is not as complete as could be desired, it is believed that all of the large floods which have occurred within the last 100 years are included in the table.

There are no evidences of any flood ever having occurred on this creek larger than that of August 30, 1940, but it is possible that such floods may have occurred. Flood heights since 1930 are not entirely comparable to those prior to that date because of the changes made in the Hominy Creek Valley by the construction of the American Enka Corporation plant.

Although there were floods of noteworthy proportions on the French Broad in 1850, 1852, and 1875, no reference has been found to these having occurred on Hominy Creek.

TABLE 17

CREST STAGES OF DAMAGING FLOODS

AND

ESTIMATED FLOOD DAMAGES

WITH DEVELOPMENT AS IN 1941 CAUSED BY REPETITION OF PAST FLOODS

HOMINY CREEK

Date of Flood	Elevation at Enka Feet	Total Flood Damage
June 1873	2055	$ 1,000
June 1876	2059	12,000
Sept. 11, 1893	2058	2,000
July 1896	2058	2,000
Oct. 1900	2056	1,300
May 21, 1901	2058	2,000
Feb. 28, 1902	2061	39,500
Aug. 31, 1910	2060	30,400
July 16, 1916	2055	1,000
Aug. 16, 1928	2055	1,000
Oct. 16, 1932	2053.1	
Jan. 8, 1935	2056.0	1,300
Oct. 16, 1936	2057.9	2,000
Aug. 13, 1940	2057.9	2,000
Aug. 30, 1940	2061.6	45,500*
Total		$143,000

* Actual damages in 1940 were $921,000.

Elevation datum is U. S. Coast and Geodetic Survey, 1936 Supplementary Adjustment. American Enka Corporation datum is 2.6 feet above 1936 Supplementary Adjustment datum.

Bankfull stage at Enka occurs at elevation 2056. Some flooding of lowlands below Enka occurs at elevation 2054 on the Enka gage. Appreciable damage does not begin until stages above 2056 are reached.

Elevation for the last five floods are from gage records. Previous flood elevations estimated from the best available information.

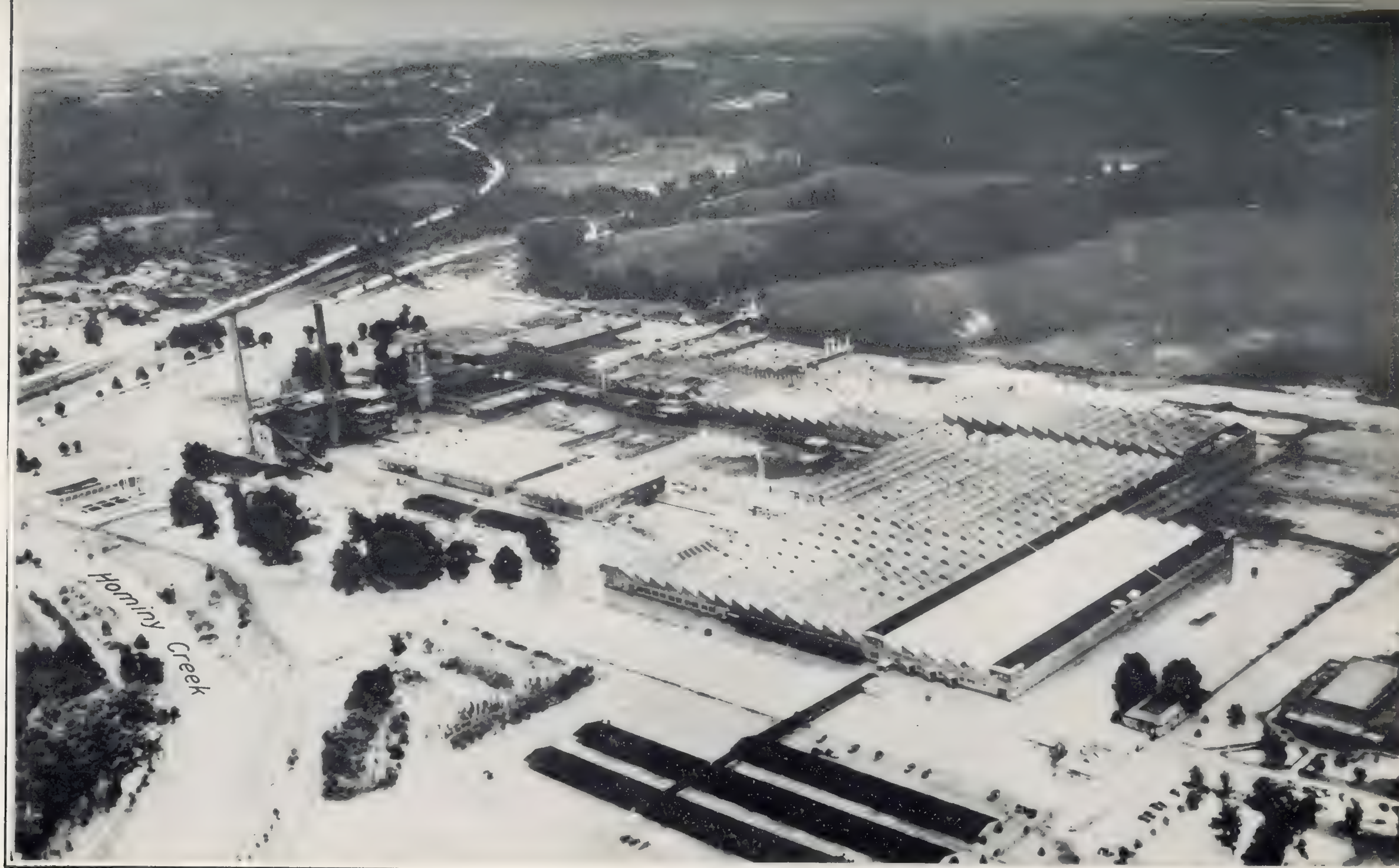


FIGURE 14 — HOMINY CREEK FLOODS LARGE RAYON PLANT

American Enka Corporation plant suffered tremendous damages from flood of August 30, 1940. The flood was three feet higher at the crest than shown by the picture.

(Asheville Citizen-Times photo)

Magnitude of Past Floods

Data are available from which to estimate flood volumes and peak rates of flow for only those floods since records were begun at the Enka filter plant. The following table gives this information.

TABLE 18

FLOOD FLOW AND RUNOFF

HOMINY CREEK AT ENKA

(Drainage Area 94 Square Miles)

Date	Average Rainfall Inches	Gage Height Feet	Peak Discharge Amount c.f.s.	Peak Discharge Per Sq.Mi. c.f.s.	Surface Runoff Ac.Ft.	Surface Runoff Ins.	Runoff To Rainfall Percent
Oct. 16, 1932	--	2053.1	1,700	19	2,500	0.5	--
June 8, 1935	--	2056.0	3,400	39	2,500	0.5	--
Oct. 16, 1936	--	2057.9	4,800	56	6,700	1.3	--
Aug. 13, 1940	7.1	2057.9	4,800	56	6,300	1.3	18
Aug. 30, 1940	7.7	2061.6	12,800	149	13,700	2.8	36

Flood Damages

With the exception of the American Enka plant and small commercial developments at Candler, houses and buildings are located well above high water. Flood damage is ordinarily limited to the overflow of bottom lands and washing away of small bridges. Flooding of roads and stores at Candler begins with a rise equal to that of the mid-August 1940 flood. The tracks of the Southern Railroad are overflowed by high floods in the vicinity of the Enka plant and at a point about a mile upstream. The roadbed is subject to scour at several points above Candler. On upper Hominy Creek and on the tributaries the bottoms are narrow and are subject to overflow and scour. Roads and bridges are also subject to flood damage.

Table 17 shows the estimated damages that would be caused by a repetition of past floods with development as it was in 1941. It will be

noted that damages are small except in a few cases. Prior to 1928, damage was limited to loss of crops and damages to railroad, roads, and small bridges. The table shows 1940 flood damages estimated with the Enka plant protected by the new levees built after the flood. Actually, the total damages in 1940 were $921,000. Much larger floods than 1940, which are possible, would result in damages even greater than those which occurred in 1940.

Appendix B contains further information on flood damages.

Damages from Flood of August 30, 1940

This flood is the only one on Hominy Creek which has caused large damages. This is because of the damages to the Enka plant which did not exist in prior years when large floods occurred on Hominy Creek. Damages to this large industry overshadow those to other classes of property. The floods of 1902 and 1910 would have caused damages of the same order as that of 1940 had the Enka plant been built prior to those years.

The following is a summary of the estimated damages which occurred during the flood of August 1940 classified according to type:

Industrial	$866,600
Commercial	7,400
Domestic	7,100
Highways	4,400
Railroad	21,000
Utilities	5,100
Agricultural	9,400
Total	$921,000

Flood Control Plans

Two principal methods of flood control were investigated for Hominy Creek, first, that of storage reservoirs and second, that of providing levee protection to the American Enka Corporation plant, the chief point of damage in the Hominy Creek basin.

The control of Hominy Creek floods by a storage reservoir is complicated by the fact that the Southern Railway and the main U. S. Highway 19 extend up the creek valley. This situation practically eliminates the control of floods on Hominy Creek by a storage reservoir on the main creek even though such a reservoir would be beneficial for flood control both along Hominy Creek and at Asheville. The locations of the railroad and highway are such that damage to these could be eliminated only if they were removed from the creek valley or if a combination of storage reservoirs could be built upstream on the tributaries to Hominy Creek.

Investigations of the possibilities of one or more reservoirs in this basin to give protection to the Enka plant and to the railroad, highways, and agricultural interests indicate that the cost for such protection would be several hundred thousand dollars. The amount of benefits to the railroad, highways, and agricultural interests is relatively small and would not justify such an expenditure. Neither are the benefits from any such reservoir as a part of the plans for protecting Asheville sufficient to warrant its being included in the plan. The benefits to the Enka plant would be large but it is possible to provide protection to that plant by enlargement of the existing levees at a considerably less cost than that for reservoirs. Hence levees are the most feasible method of flood protection for the prevention of large flood losses in the Hominy Creek basin.

Levee Protection

About eleven years ago the American Enka Corporation constructed a large industrial plant for the manufacture of rayon on the broad flat on the right bank of Hominy Creek eight miles upstream from the mouth. The location of the plant is shown on plate 31. A larger scale plan of the plant and vicinity is shown on plate 32.

At the time of the construction of the plant, the creek was relocated through the bottom and a levee was built around the plant. This levee, however, did not protect against the late August 1940 flood when the entire plant was overflowed, resulting in heavy damage. Since that flood the levee has been reconstructed and certain other works built. The reconstructed levee

averages about two feet higher than the 1940 flood, but the levee also eliminates the storage that the overflowed plant area provided in 1940. Such a flood confined by a levee would therefore be somewhat higher in the future.

The net result of the new levee and the elimination of storage is that the capacity of the Hominy Creek valley opposite the Enka plant is only equal to that of a flood slightly larger than that of August 1940. The reconstructed Enka levees provide flood protection against floods only about one-fifth of that which may be expected to occur from a watershed of the character and size of Hominy Creek located in this region.

The peak flow for such a flood is estimated as 55,000 cubic feet per second which is 640 cubic feet per second per square mile of drainage area. Such a peak rate of flood flow is large but it is amply supported by the runoff from several watersheds in western North Carolina in the mid-August 1940 storm where peak rates were experienced of the order of those proposed for Hominy Creek. Some of these high rates, as determined by the Asheville District, U. S. Geological Survey, are shown in the following table.

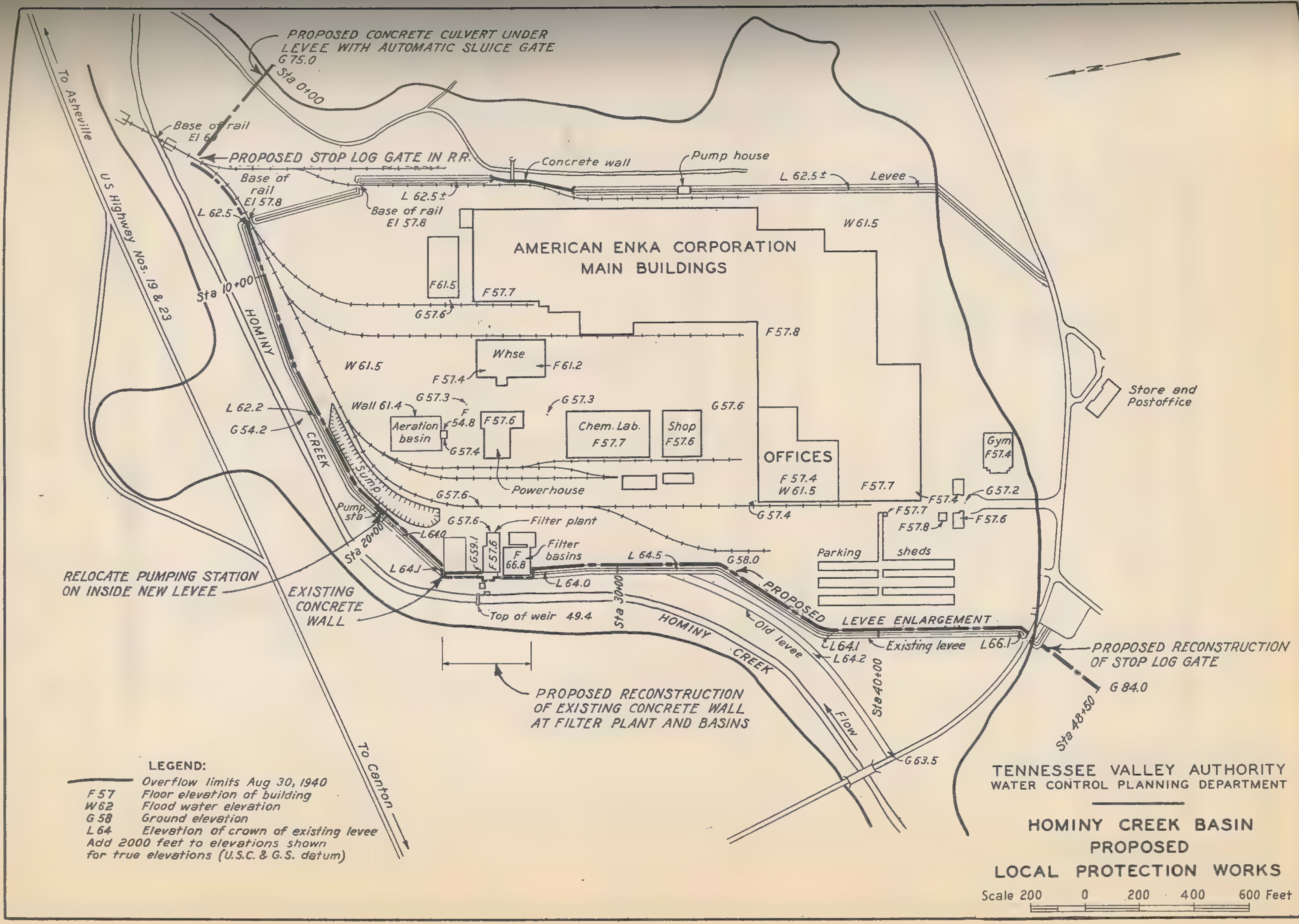
TABLE 19

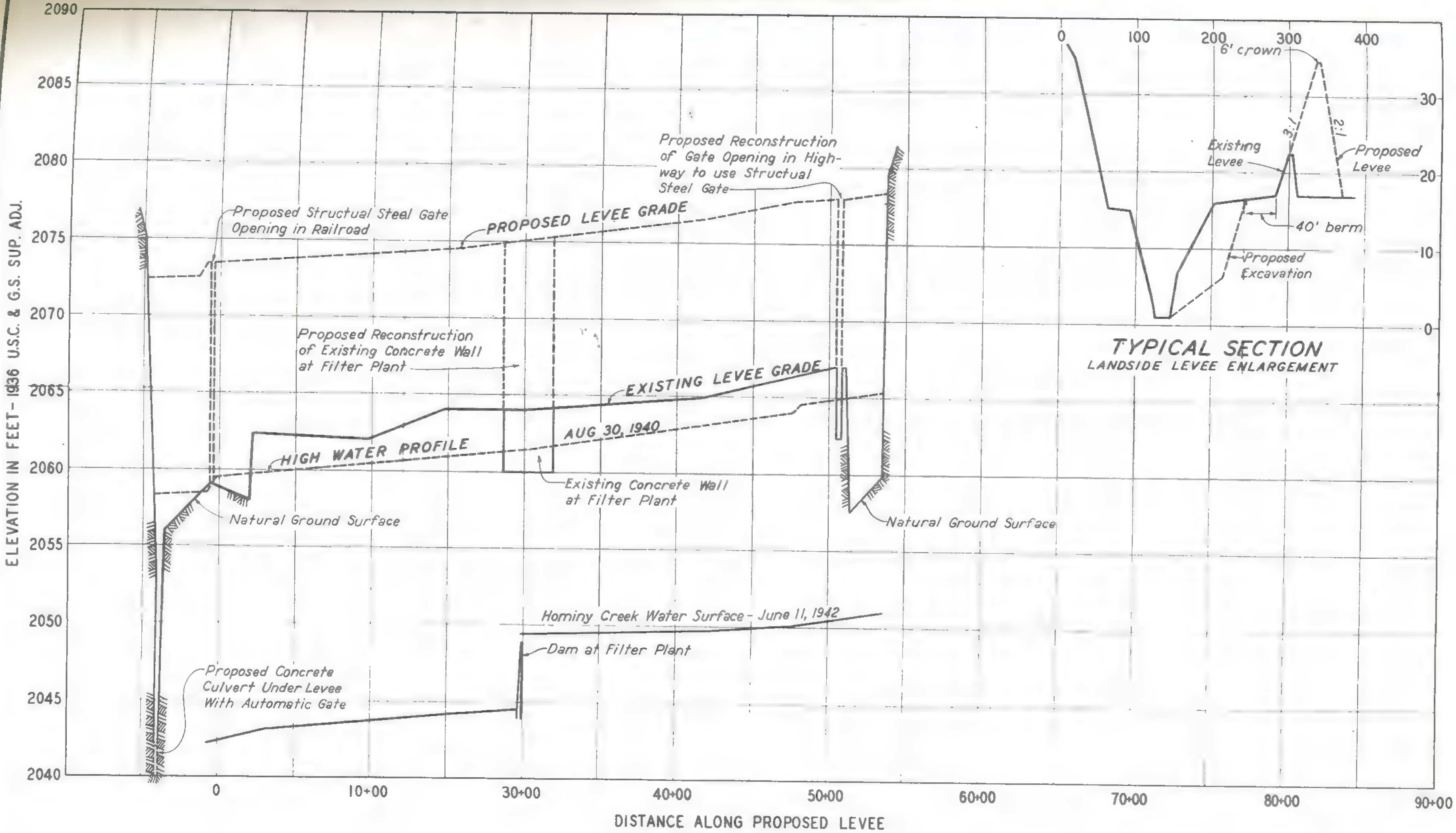
PEAK DISCHARGE RATES

MID-AUGUST 1940 FLOOD

Stream	Drainage Area Square Miles	Peak Discharge c.f.s.	Rate Per Square Mile c.f.s.
Linville River	65.0	39,500	605
Warrior Fork	80.5	38,500	476
John's River	69.1	30,800	444
Wilson Creek	66.0	99,000	1,500
Elk Creek	50.1	71,500	1,420

To provide for a flood having a peak rate of flow of 55,000 cubic feet per second, it is necessary to raise the existing earth levee along


TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT
HOMINY CREEK BASIN
PROPOSED
LOCAL PROTECTION WORKS
Scale 200 0 200 400 600 Feet
LEGEND:
Overflow limits Aug 30, 1940
F 57 Floor elevation of building
W 62 Flood water elevation
G 58 Ground elevation
L 64 Elevation of crown of existing levee
Add 2000 feet to elevations shown
for true elevations (U.S.C. & G.S. datum)
PROPOSED CONCRETE CULVERT UNDER LEVEE WITH AUTOMATIC SLUICE GATE
G 75.0
Sta 0+00
PROPOSED STOP LOG GATE IN R.R.
Concrete wall
Pump house
Levee
L 62.5 ±
Base of rail El 57.8
AMERICAN ENKA CORPORATION
MAIN BUILDINGS
W 61.5
F 61.5
F 57.7
G 57.6
F 57.8
Whse
F 57.4
F 61.2
G 57.3
Wall 61.4
Aeration basin
F 54.8
G 57.4
F 57.6
Powerhouse
Chem. Lab. F 57.7
Shop F 57.6
OFFICES
F 57.4
W 61.5
F 57.7
Gym F 57.4
G 57.2
F 57.6
F 57.8
Store and Postoffice
Parking
sheds
Filter plant
Filter basins
F 66.8
G 59.1
L 64.0
L 64.1
L 64.5
G 58.0
PROPOSED LEVEE ENLARGEMENT
Existing levee
Old levee
L 64.2
L 66.1
PROPOSED RECONSTRUCTION OF STOP LOG GATE
G 84.0
Sta 48+50
Sta 40+00
Sta 30+00
Sta 20+00
Sta 10+00
G 63.5
Flow
HOMINY CREEK
Top of weir 49.4
PROPOSED RECONSTRUCTION OF EXISTING CONCRETE WALL AT FILTER PLANT AND BASINS
EXISTING CONCRETE WALL
RELOCATE PUMPING STATION ON INSIDE NEW LEVEE
Pump sta
Sump
L 62.2
G 54.2
L 62.5
To Asheville
US Highway Nos. 19 & 23
To Canton



TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

PROFILE
OF
PROPOSED LEVEE
ENKA, NORTH CAROLINA

Hominy Creek opposite the Enka plant about 12 feet and to construct short sections of new levee to tie in to high ground at each end. The improvements necessary to provide this protection are shown on plate 32. Plate 33 is a profile and typical section of the levee.

The material for constructing the levee would be taken from the Hominy Creek Valley, enlarging the channel opposite the industrial plant. At the filter plant, it would be necessary to reconstruct a short section of the existing concrete wall since there is not room for an earth levee at this point. At the eastern end, near where the new levee would tie into the high ground, the levee crosses a small drain which has a watershed of approximately 190 acres. This drain would be given an outlet into the Hominy Creek channel through a concrete sluiceway equipped with an automatic flood gate to prevent Hominy Creek flood water from backing into the area behind the levee. During floods in Hominy Creek, runoff from this drain may be ponded temporarily on the landside of the new levee. Such water would not interfere with the Enka plant because the present back levee of the Enka plant would be maintained and would give ample protection against flooding from any runoff that could come from this small drainage area during the short time that Hominy Creek would be at flood stages.

Degree of Protection Provided

Construction of the proposed levee would provide protection against any flood that can be foreseen as possible on the Hominy Creek watershed. Floods such as those of 1902, 1910, and 1940 would be discharged through the floodway opposite the Enka plant with a large margin of safety. The 1940 flood would be about 12 feet below the top of the levee. The Hominy Creek flood protection levees would have no effect on the city of Asheville and are of no benefit elsewhere than on Hominy Creek itself.

Estimate of Cost

The following is a condensed estimate of the cost of levee improvements. Details are given in Appendix E.

Earth embankment - - - - - - - - - - - - - - - - - -	$ 40,000
Concrete wall - - - - - - - - - - - - - - - - - -	11,200
Flood gates at railroad and highway - - - - -	24,700
Sluiceway for drain - - - - - - - - - - - - - -	2,400
Other costs - - - - - - - - - - - - - - - - - - -	3,000
Total -	$ 81,300
Contingencies, Engineering and Administration	32,700
Total Project cost - - - - - - - - - - - - - - - -	$114,000

Benefits

The damages which have occurred in the Hominy Creek Basin in the past are not indicative of the damages that might occur in the future as a result of floods on this stream, except in the case of the late August 1940 flood. At that time, the industrial damage on Hominy Creek was $866,000. Present local protection works at the Enka plant would prevent damages from a flood the size of that which occurred in 1940 but would not prevent damages from floods only slightly larger. Should such a flood occur, the damages would be as great or possibly greater than those of August 1940. Such a large potential damage indicates the need for protection and the desirability of constructing works which will give complete protection.

The cost of the proposed levee improvements in the Hominy Creek Valley is only about 15 percent of the damages which occurred during the August 1940 flood and is a lesser percent of the damages that would occur from a flood which is within the realm of possibility for Hominy Creek. The margin of benefits over costs is obviously large.

VI. MARSHALL

The Flood Situation

Twenty-two miles downstream from Asheville on a narrow low-lying shelf on the right bank of the French Broad River is the business portion of the town of Marshall. The residential section is on the high lands back of the town far above the river. Whenever large floods occur, the river overflows the business section of the town to a depth of several feet and damages are considerable. In the flood of August 30, 1940, damages at Marshall were $93,000. If the 1916 flood were to recur with development as it was in 1941, it is estimated that damages would be $234,000. Plate 34 shows the town of Marshall and the extent of the 1916 and 1940 overflows.

The river at Marshall is of a different character than that upstream from Asheville. Here it flows through a precipitous gorge, 400 to 1000 feet deep, characterized by rapids, low waterfalls, and marked variations in the width of channel. Marginal flood plains through this part of the river are very narrow or non-existent.

When the railroad was built from Asheville towards Knoxville, a location generally hugging one bank or the other of the French Broad offered the most practical way of getting through the intervening mountains. The roadbed was constructed in many places below high water levels in the river. As a result of this, the railroad is subject to very large damages during major floods. In the flood of July 1916, damages in the 57 miles of railroad from Asheville to Bridgeport near Newport, Tennessee, are estimated at $370,000. In August 1940, damages were $80,000, of which $60,000 was at the town of Marshall.

U. S. Highway 70 follows some reaches of the French Broad from Asheville to Marshall. Generally, however, the highway follows a location well above high water. A large flood such as that of July 1916 would damage this main highway about $37,000.

Summary of Flood History

The following is a summary of the flood history at Marshall.

1. The flood of July 1916 is the largest that has occurred on the Marshall section of river during the past 150 years.

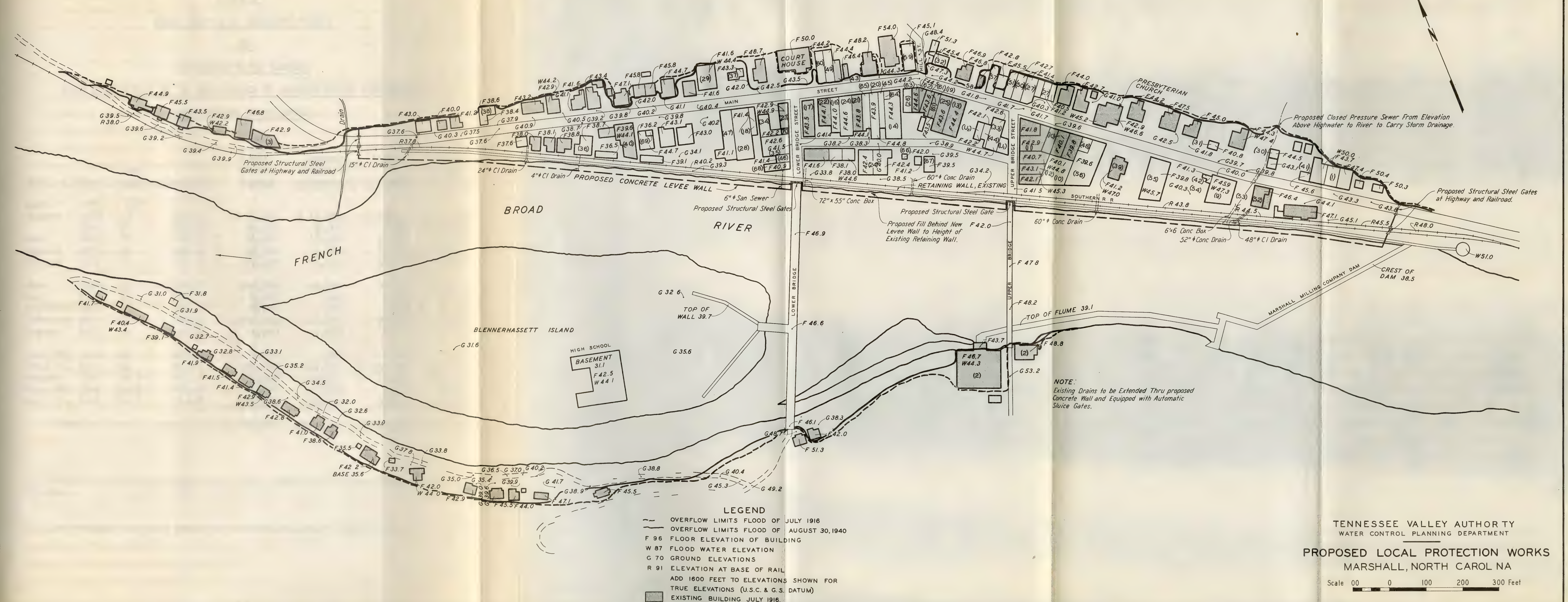
2. The flood of August 30, 1940, was the second highest flood and was from 1-1/2 to 3-1/2 feet lower than the 1916 flood through Marshall.

3. A major flood may occur at Marshall as the result of a storm over all or part of the 400 square miles of tributary area downstream from Asheville, including Ivy River, Sandymush, and smaller creeks; the August 30, 1940, flood was such a flood.

4. Large damages occur to Marshall and to the Southern Railway from Asheville to the mouth of Pigeon River during major floods; due to the narrow width of overflow, other damage is minor.

Conditions at Marshall

Plate 34 is a map showing the buildings in the town of Marshall with elevations of floors, ground surface elevations, high water elevations, and the extent of the flooded territory in 1916 and 1940. Due to the steep hillsides which flank the town, the area covered in 1916 does not greatly exceed that covered in 1940. The existing buildings in 1916 are shown on this map. While these buildings obstructed the flood plain at that time, the considerable number of additional buildings constructed since 1916 have made conditions worse. Upstream from Marshall, highway reconstruction and railroad adjustment just prior to the August 1940 flood extended the embankment somewhat into the river channel. This may have had some effect in altering the direction of currents in the 1940 flood as compared with those in 1916. The Gudger Warehouse and the Southern Railway Depot both withstood the 1916 flood, but in the late August 1940 flood, the Gudger Warehouse was washed from its foundations, carried several hundred feet down Main Street and lodged across the street between the Presbyterian Church and the opposite building. The depot was wrecked and distorted and had to be rebuilt. Even though the 1940 flood was lower than the 1916 high water, the nature of the flow was evidently not the same.



LEGEND

- OVERFLOW LIMITS FLOOD OF JULY 1916
- OVERFLOW LIMITS FLOOD OF AUGUST 30, 1940
- F 96 FLOOR ELEVATION OF BUILDING
- W 87 FLOOD WATER ELEVATION
- G 70 GROUND ELEVATIONS
- R 91 ELEVATION AT BASE OF RAIL
- ADD 1600 FEET TO ELEVATIONS SHOWN FOR TRUE ELEVATIONS (U.S.C. & G.S. DATUM)
- EXISTING BUILDING JULY 1916.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

PROPOSED LOCAL PROTECTION WORKS
MARSHALL, NORTH CAROLINA

Scale 100 0 100 200 300 Feet

TABLE 20

CREST STAGES OF DAMAGING FLOODS

AND

ESTIMATED FLOOD DAMAGES

WITH DEVELOPMENT AS IN 1941 CAUSED BY REPETITION OF PAST FLOODS

LOWER FRENCH BROAD RIVER

Date of Flood		Gage Height	Elevation	Total Flood Damage	Damages Asheville to Marshall	Damage at Marshall	Damage Below Marshall
April	1791	(a)					
August	1796	17	1641.5	$ 64,600	$ 13,450	$ 17,270	$ 33,880
	1810	15	1639.5	24,300	5,600	5,600	13,100
May	1845	17	1641.5	64,600	13,450	17,270	33,880
August	1850	16	1640.5	42,600	9,500	10,300	22,800
August	1852	18	1642.5	106,100	22,560	32,600	50,940
June	1876	21	1645.5	246,500	40,100	90,950	115,450
May	1901	13	1637.5	8,000	900	2,000	5,100
December	1901	13	1637.5	8,000	900	2,000	5,100
February	1902	21	1645.5	246,500	40,100	90,950	115,450
August	1910	14	1638.5	12,900	1,375	3,000	8,525
July 11,	1916	13	1637.5	8,000	900	2,000	5,100
July 16,	1916	24	1648.5	725,200	142,950	234,300	347,950
August	1928	16.3	1640.8	42,600	9,500	10,300	22,800
Aug. 14,	1940	14.5	1639.0	12,900	1,375	3,000	8,525
Aug. 30,	1940	20.3	1644.8	214,400	36,090	93,060	85,250
Total - - - - - - - - - - - -				$1,827,200	$338,750	$614,600	$873,850

All stages are at the original site of the gage at the upper bridge, Mile 125.18.

(a) No definite data are available for the height of this flood.

On Blennerhassett Island is located the Marshall High School. The basement of this school is flooded at a stage of 9 feet and at a stage of about 13 feet appreciable damages begin to occur. Since its construction, this school has been subject to flood damage repeatedly even by small floods which affect little else.

Floods Heights and Occurrences

Table 20 is a compilation of crest stages at Marshall, North Carolina, for the damaging floods which have occurred since 1791. This table has been made up from the best available data. The study of past floods at Asheville has been utilized to determine flood stages at Marshall for large floods which are known to have occurred at Asheville.

Magnitude of Past Floods

There is no regular stream gaging station on the French Broad River at Marshall and information is not available from which the volume of past floods can be determined. Peak rates of flow for the largest floods which are known to have occurred on the French Broad at Asheville are estimated and are given in the following table:

TABLE 21

FLOOD FLOW AND RUNOFF

MARSHALL, NORTH CAROLINA - FRENCH BROAD RIVER

Date	Average Rainfall Inches	Gage Height Feet	Peak Discharge Amount c.f.s.	Peak Discharge Per Sq.Mi. c.f.s.	Surface Runoff Ac. Ft.	Surface Runoff Ins.	Runoff To Rainfall Percent
July 1916	9.0	24.0	98,000	73	422,000	5.1	56
Aug. 30, 1940	7.3	20.3	61,000	45	175,000	2.1	29

Flood Damages

Table 20 shows the estimated damages that would be caused by repetition of past floods on the Lower French Broad Basin from Asheville to Newport. The data on early floods is meager and no doubt a number of these occurred of which there is now no trace. Damages from such floods would increase the total flood damage considerably. The table shows total damages for the entire river downstream from Asheville and also damages from Asheville to Marshall, at Marshall, and downstream from Marshall. The damages at Marshall itself are the most significant figure because local protection works are described in this section of the report designed to eliminate damages at Marshall. Such protection works at Marshall would not reduce damages either above or below the town. The construction of storage reservoirs on the Upper French Broad above Asheville would reduce flood heights on the river below Asheville for floods originating in the Upper French Broad watershed and would reduce damages from such floods.

Appendix B contains further information on flood damages.

Flood of August 30, 1940

This flood caused damages on the river below Asheville estimated at $213,200. Major losses were those at Marshall where the flood was 2-1/2 to 3-1/2 feet below the record flood of July 16, 1916, and resulted in damages of about $93,000. The main street in the town was under water for its entire length and water entered all of the buildings on this street excepting a few in the center of town near the courthouse. Business firms throughout the town were damaged severely. The railroad suffered heavy damage to its tracks and the depot collapsed due to the flood.

Damages for Repetition of 1916 Flood

It is estimated that the total damages on the French Broad River downstream from Asheville for the 1916 flood would be $725,000. In Marshall alone the damages would be $234,000. Heavy damages would result in Marshall particularly to industrial and commercial establishments and to the Southern Railway.

Flood Protection Plans

Floods which affect Marshall may originate either principally over the French Broad watershed upstream from Asheville, as in the case of the great July 1916 flood, or may result from heavy rainfall over the watersheds of the several tributary streams which empty into the French Broad between Asheville and Marshall. The total drainage area at Marshall is 1340 square miles, of which 945 are above Asheville and 395 between Asheville and Marshall.

Floods Originating Above Asheville--For those floods which come from the Upper French Broad watershed above Asheville, the flood protection plans proposed for Asheville and the Upper French Broad Valley will reduce flood heights at Marshall. However, neither of the plans for Asheville will effect sufficient reduction in flood heights to protect Marshall from flooding. The discharge past Asheville for floods for which the protection works there are designed plus the increase from the runoff from the area between Asheville and Marshall would produce a flood at Marshall of a height to cause overflow.

Floods Originating Below Asheville--Plate 1 shows the several principal tributaries of the French Broad River between Asheville and Marshall. The largest of these is Ivy River, drainage area 158 square miles, with Sandymush Creek next in size, drainage area 80 square miles. These tributaries are so located on both sides of the French Broad River and their combined area is sufficient so that a large flood may be caused at Marshall from runoff contributed by this area practically independent of the flow coming past Asheville. Whatever the latter flow happens to be will augment the flood in any case. The late August 1940 flood was produced from the runoff of the area between Asheville and Marshall. Heavy rainfall over the left bank creeks and over part of the right bank tributaries resulted in a flood crest at Marshall several hours prior to the crest at Asheville. The peak discharge at Marshall during this flood is estimated at 61,000 cubic feet per second. More than 70 percent of this came from the area below Asheville, which is only about 30 percent of the total drainage area at Marshall. Although this flood did great damage at Marshall, the peak flow was only about one-half of that which may be expected to occur from the drainage area between Asheville and Marshall.

FIGURE 15 — MARSHALL'S MAIN STREET FLOODED AUGUST 30, 1940

The height reached by the flood at the crest is shown by the water lines on the buildings and is approximately 3 feet higher than the water in the picture.

FIGURE 16 — SOUTHERN RAILWAY TRACKS BADLY WASHED AUGUST 1940 AT MARSHALL

Over 1000 feet of track were carried into the river at this location. The Southern Railway station was also partially destroyed by the flood. One span of the upper river bridge shown in the background was washed out by the flood.

In addition to the area between Asheville and Marshall, there are 377 square miles of uncontrolled area upstream from Asheville under the Regional Plan and 185 square miles under the plan for Asheville Only. In either case, it is possible for a considerable contribution to flood peaks at Marshall to come from this area.

Ivy River--The Ivy River contribution to the August 1940 flood was relatively moderate by comparison with what is to be expected from that watershed. Runoff from Ivy River alone with only moderate contributions from other streams could produce a major flood at Marshall. Floods larger than that of August 30, 1940, have occurred on the Ivy River. The highest flood known was that of June 1876 which was about 3-1/2 feet higher than the 1940 flood. Other floods larger than that of 1940 occurred in 1902, 1906, 1916, and 1927. The greater part of the Ivy River watershed has been cleared and is under some form of cultivation. Many of the lands under cultivation are steep hillsides and hilltop land which is subject to severe erosion. These conditions are conducive to high surface runoff and to a heavy silt burden for the Ivy River.

The river flows for the most part in a gorge section, pursuing a tortuous winding course through the surrounding high rolling hills. Near the mouth, the channel slope is 18 feet per mile, increasing to 45 feet per mile near Barnardsville. Banks are generally quite high with little or no adjacent bottom lands except near the upper end of the river where they reach a maximum width of about one-eighth of a mile.

An investigation of the Ivy River watershed showed that there are no feasible sites for storage reservoirs on this stream which could be utilized for the control of floods. It does not appear feasible to control Ivy River floods by engineering methods. The large amount of cleared hillside land in the watershed makes this a problem where improved agricultural practices, including land use and management with the objective of better vegetal cover, offers the best hope for the lessening of flood heights and erosion and conservation of water on this watershed.

Sandymush Creek--Sandymush Creek is located on the opposite side of the French Broad from the Ivy River and flows into the French Broad a short distance above the mouth of Ivy River. This creek and its principal tributary, Turkey Creek, contributed a considerable volume of water to the late August 1940 flood. The drainage area of 80 square miles is of rugged terrain, a large part of which is opened up and under cultivation. The flood of August 30, 1940, was the most severe in the history of the creek although that of June 1876 was very nearly as severe. Damages from floods in the basin are slight due to the narrow bottoms.

An investigation was made of the Sandymush Creek watershed for possible storage reservoir sites, but as in the case of Ivy River, the topography of this creek does not lend itself to storage reservoirs. Conditions in the watershed with regard to character and usage of land are similar to those in the Ivy River watershed and present an opportunity for improved land use and management to create better vegetal cover as a means of reducing flood heights and erosion.

Levee Along Marshall Water Front

Analysis of the flood situation at Marshall shows that whatever flood control plans are constructed for Asheville and the Upper French Broad, Marshall would still be endangered by floods arising from the nearly 400 square miles of watershed between Asheville and Marshall. Augmented by the flow from above Asheville, since control of floods from the area below Asheville by storage reservoirs has been investigated and found not feasible, the only salvation from floods for Marshall is local protection works constructed at the town.

Such protection would be a levee located on the right side of the French Broad. The flood plain at Marshall is practically all occupied by existing buildings, highway, and railroad. The railroad is immediately adjacent to the river. On the river side of the railroad is a masonry retaining wall extending down to the natural river bed. Nowhere is there sufficient room for an earth levee to be constructed. It would be necessary, therefore, to construct a concrete levee wall which in general would follow

the river side of the railroad opposite the town and tie into higher ground at the two extremities of the town. The location of the proposed concrete levee is shown on plate 34 and the profile for three alternate heights of levee is shown on plate 35.

Beginning at the bottom of the river and tying in to the solid rock of the river bed, a concrete wall would be constructed immediately riverward of the existing rock retaining wall.

The height to which the concrete wall would be carried could be varied depending on the degree of protection provided. For complete protection, the wall should be high enough not to be overtopped by the greatest flood that could originate on the local area downstream from Asheville plus some flow from above Asheville. Such a flood is estimated as 120,000 cubic feet per second maximum peak rate. Protection against a flow of this magnitude would be more than ample for floods that might originate above Asheville after flood protection works are constructed on the Upper French Broad watershed. The cost of such complete protection is estimated to be $767,000.

In view of this high cost, a lesser height of wall might be considered for Marshall even though, because of the urban character of the property behind the levee, protection against the maximum flood is desirable. Two such levee wall designs have been made, one to protect to a height sufficient to prevent overflow during floods of the magnitude of that of July 1916, the other to protect against floods of the size of that of August 1940. The estimated costs for these are $516,000 and $297,000 respectively. The latter is the cheapest of all three plans but its benefits are also the least.

Where the levee location crosses the river bridge approach streets and the Southern Railway tracks, structural steel gates would be provided which would be used to close the openings in time of flood. For the levee to the height of the 1940 flood, the depth of openings is such that timber stop logs would be used at the openings during floods.

Local drainage from the area behind the levee during those times when the French Broad River is in flood could either be allowed to pond during

the short time that the river is high or removed by a small pumping plant. Present outlets into the river for sewers could remain in their present locations with automatic valves where each goes under the levee.

Estimate of Cost

The following are condensed estimates of cost of the respective levee plans.

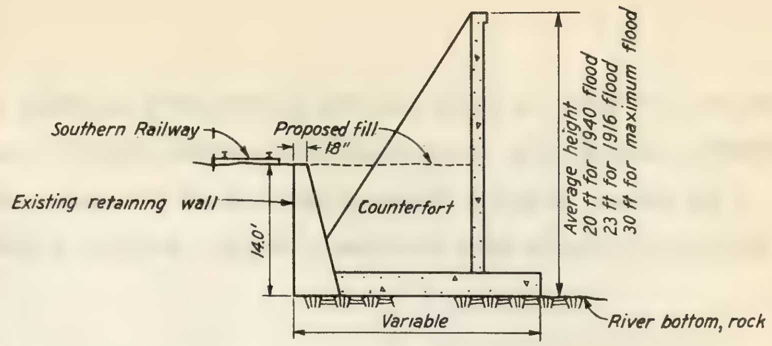
Type of Work	Plan A Complete Protection	Plan B Protection for 1916 Flood	Plan C Protection for 1940 Flood
Concrete Wall	$ 448,000	$ 334,600	$ 200,500
Structural Steel Gates for highway and railroad openings	39,000	23,400	1,000
Underdrains	10,600	10,600	10,600
Total	$ 547,600	$ 368,600	$ 212,100
Contingencies, Engineering and Administration	219,400	147,400	84,900
Total Project cost	$ 767,000	$ 516,000	$ 297,000

Appendix E gives a detailed estimate for each plan.

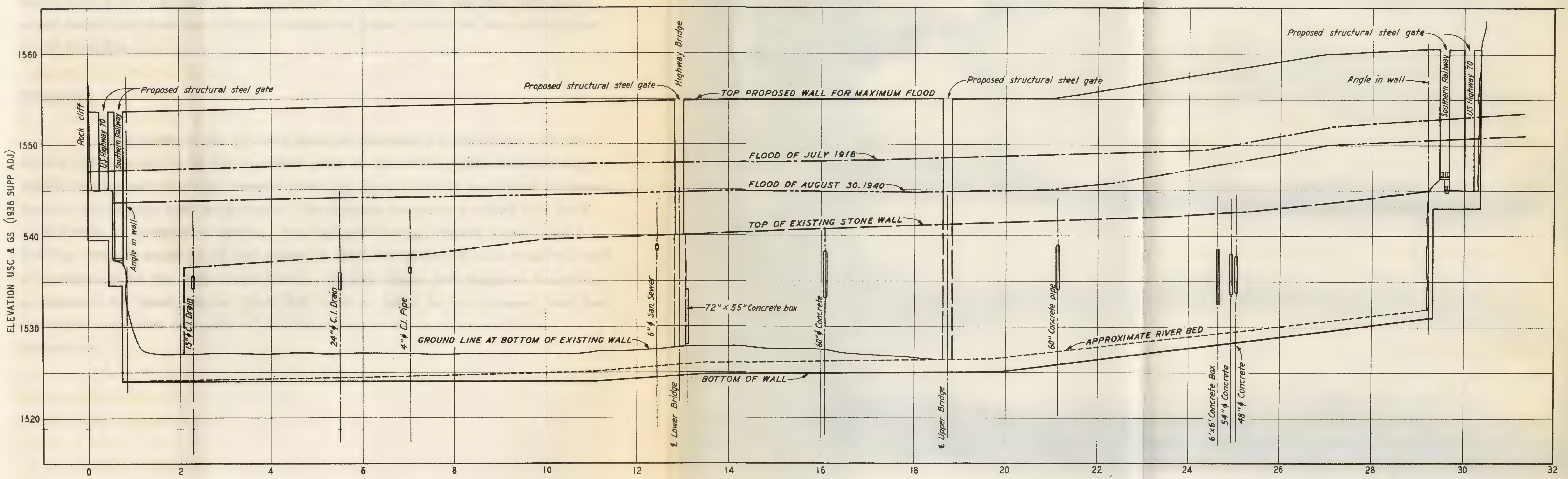
Protection Provided

Varying degrees of protection of the town of Marshall would be provided by the three plans. During the past 66 years the height of the 1940 flood has been slightly exceeded twice and has been topped by about 4 feet on one occasion. With the wall built to just above the 1940 height, only the 1916 flood would have overflowed the levee in the past 66 years.

If the wall were built to the 1916 flood level, then it would be as high as any known flood at Marshall. This should not be interpreted that the wall would not be topped by some future flood for the 1916 flood, although high, is by no means the maximum that can reasonably be expected at Marshall.



TYPICAL SECTION
PROPOSED CONCRETE LEVEE



TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

PROFILE
OF
PROPOSED CONCRETE LEVEE
MARSHALL, NORTH CAROLINA

If some form of partial protection should ever be constructed at Marshall, then proper means of permanent notification to all future inhabitants of the town should be taken to warn them against a false sense of security from overflow during floods larger than that for which the works provide.

None of the plans proposed would protect the mills or houses on the left bank of the river at Marshall. The school on Blennerhassett Island would also not be protected. Protection for the school and the left bank other than that from the storage reservoirs above Asheville does not appear to be feasible.

Benefits

The extent of the flooded area at Marshall is restricted to the narrow plain occupied by the business part of the town. This necessarily limits the amount of total damages from any flood and for the plans for protection which have been worked out, the damages are only a third to a half of the cost of protection works. Capitalized average annual flood losses for the past 65 years is of the order of $250,000 which is less than the cost of protection to the 1940 flood level. In all cases, the tangible benefits, as measured by flood damages that have been or would be experienced, are considerably less than the cost of the necessary works to provide flood protection.

VII. PIGEON RIVER

Pigeon River flows into the French Broad at Newport, Tennessee, about 70 miles downstream from Asheville and does not contribute to floods on the French Broad above Newport. The watershed of Pigeon River lies adjacent and to the west of the Upper French Broad watershed and its flood problems are separate from those in the Upper French Broad Basin. The chief points in common between the Upper French Broad and Pigeon watersheds are that they both lie in the same general region and are subject to flood damage. Storms which cause floods in one watershed sometimes but not always do so in the other. In July 1916, when the Upper French Broad had its greatest flood, Pigeon River had no flood. In the two August 1940 floods, both streams were in flood.

The Pigeon River watershed is shown on plate 36. It contains 689 square miles of rugged terrain outlined by mountains which in the headwaters reach elevations of 6400 feet. Near the mouth of the river, elevations are about 1200 feet and in the valley at Canton, elevations are about 2600.

Canton and Waynesville are the largest towns in the area. Canton is on the main Pigeon River and is the location for the large paper manufacturing plant of the Champion Paper and Fibre Company. This plant suffered tremendous damages from both 1940 floods.

The Southern Railway from Asheville to Murphy crosses the watershed passing through Canton and Waynesville. U. S. Highway 19 generally parallels the railroad through the watershed.

The principal flood problems in the basin are confined to Canton and the valley of the river and its two forks upstream. Below the mouth of Richland Creek, the river flows through mostly wooded mountainous country, sparsely settled, and little damage results from floods. Near the mouth of the river and upstream for a few miles, the bottoms are wide enough to be farmed and floods cause crop losses in this part of the river.

Waterville Dam, a power development of the Carolina Power and Light Company, is located on Pigeon River 38 miles above the mouth. The reservoir above this dam is operated for power production, has comparatively small storage capacity, and has little effect on floods.

Lake Logan is a small reservoir on the West Fork formed by a dam built by the Champion Paper and Fibre Company as a supplementary water supply for the Canton plant. This lake has insufficient storage to have any appreciable effect on floods.

The Pigeon River watershed is in the region where intense heavy rainstorms occur usually in summer, producing large rapidly rising floods. Large damages result from those floods particularly on the Upper Pigeon including Canton. The two August 1940 floods caused damages of $611,000 in the Upper Pigeon watershed.

Investigation has been made of floods on Pigeon River and their control. This has been confined largely to the watershed above and including Canton but some consideration has also been given to the lower Pigeon.

1. UPPER PIGEON RIVER

The Flood Situation

Settlement of the better bottom lands above Canton began about 1800. Around 1880 to 1885 logs were being rafted down the Pigeon to a mill at Newport, Tennessee. Completion of the railroad from Asheville to the town of Pigeon River, now Canton, on January 28, 1882, and to Murphy in 1891 further opened up the valley. Construction of the plant of the Champion Paper and Fibre Company at Canton in 1907 was the beginning of the real development of the basin. A railroad into the forests above Canton was begun that year and extended until about 1912. This was used to bring pulp wood out to the mill until about 1933 when the rails were taken up. Since then pulp wood has been brought by rail and truck from other parts of western

PIGEON RIVER BASIN

SCALE 0 5 10 MILES

North Carolina. Considerable land at the head of both East and West Forks is now included in Pisgah National Forest.

The River and Its Valley

From Canton to Woodrow, near the confluence of the East and West Forks, Pigeon River has a slope of about 11 feet per mile. The banks are irregular and average 13 feet above low water through Canton and about 8 feet above Canton. Overflow widths are relatively narrow except at the Champion plant site in Canton where maximum overflows reach a width of over 2000 feet.

The channel slopes of both East and West Forks are considerably steeper than those of the main river. West Fork slopes about 40 feet per mile near Lake Logan and the East Fork about 50 feet per mile near Cruso. Along the West Fork, bottoms up to a half mile in width are subject to overflow. Much of this area is agriculturally developed. On the East Fork, overflow widths are somewhat less. Bottom lands are subject to scour and erosion from major floods.

Summary of Flood History

The results of the flood investigations are as follows:

1. The flood of August 30, 1940, was the highest that has occurred at Canton during a period of more than 100 years.

2. Other great floods at Canton occurred in June 1876, September 1893, August 1928, and August 1940. There is also some information relative to a large flood having occurred in 1810.

3. On West Fork the August 30, 1940, flood is the highest known, being slightly greater than that of September 1893. The flood of 1810 appears to have been somewhat on the order of these two.

4. On East Fork the flood of August 13, 1940, exceeds all other floods in the vicinity of Cruso, but below that point the June 1876 flood is the maximum.

5. Pigeon River was not in flood in July 1916 when the great flood occurred in the vicinity of Asheville and other parts of the French Broad River.

6. Large floods on the Upper Pigeon River cause heavy flood damages both to industries and commercial establishments in Canton and to the agricultural lands upstream from Canton.

Flood Heights and Occurrences

Table 22 shows the elevations reached by damaging floods on Pigeon River at the site of the present stream gage at Canton. Information relative to floods prior to the establishment of the stream gage is incomplete and fragmentary so that probably there have been other floods than those shown in the table of which there is no knowledge.

TABLE 22

CREST STAGES OF DAMAGING FLOODS

AND

ESTIMATED FLOOD DAMAGES

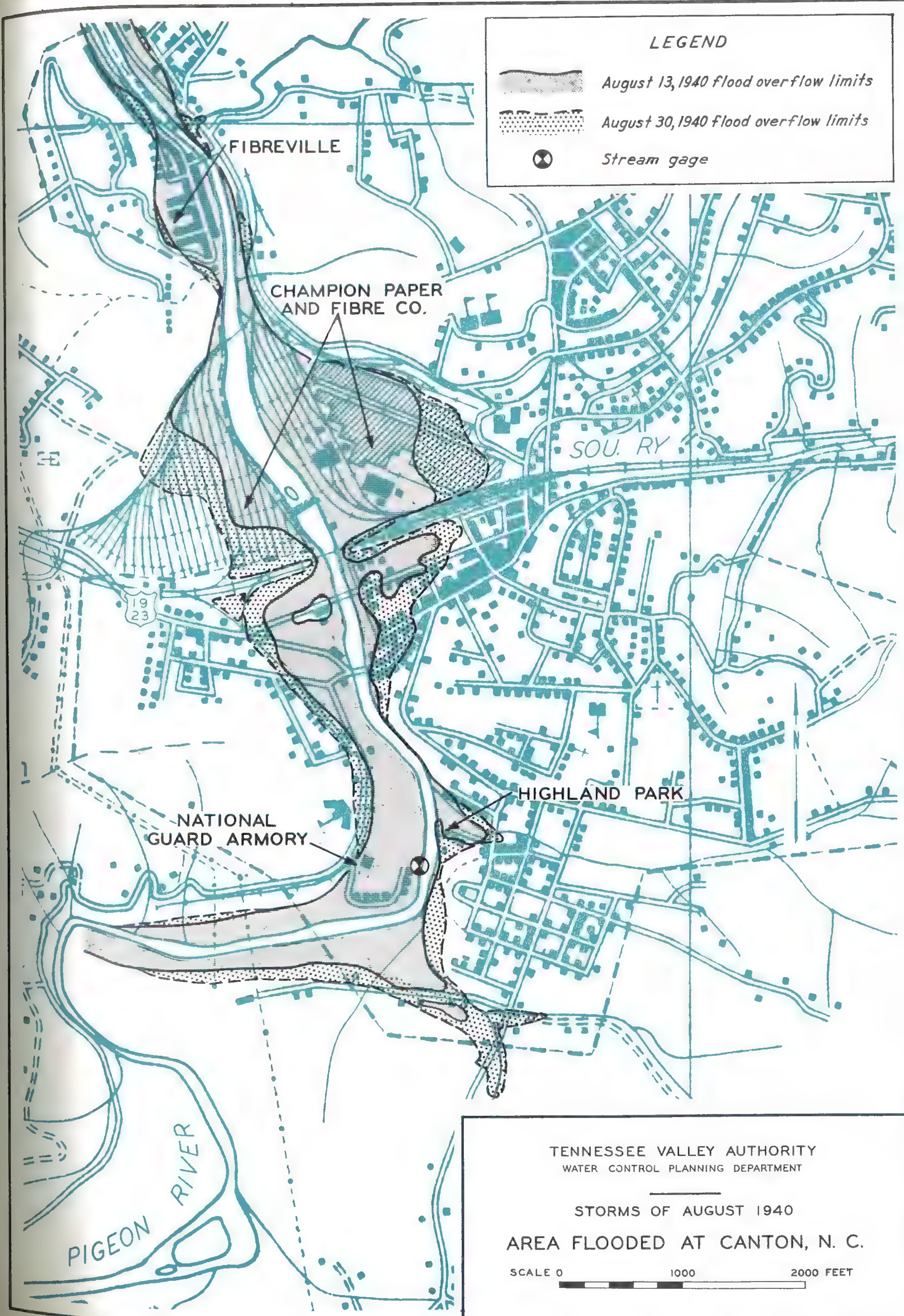
WITH DEVELOPMENT AS IN 1941 CAUSED BY REPETITION OF PAST FLOODS

UPPER PIGEON RIVER

Date of Flood		Canton Gage Height	Elevation	Total Flood Damage	Agricultural Damages	Industrial and Other Damages
Approx.	1810	20.0	2592.2	$412,000	$ 82,000	$ 330,000
June	1876	18.3	2590.5	166,600	34,300	132,300
Oct.	1879	10.0	2582.2			
Sept.	1893	17.8	2590.0	175,900	48,500	127,400
May	1901	12.0	2584.2	4,200	4,200	-
December	1901	11.0		400	400	-
Feb.	1902	12.0	2582.2	4,400	4,400	-
August	1910	12.5	2584.7	2,900	2,900	-
July 16,	1916	11.0	2583.2			
October	1918	13.0	2585.2	4,200	4,200	-
August	1928	16.4	2588.6	24,600	8,000	16,600
Aug. 13,	1940	18.0	2590.2	172,800*	36,900	135,900
Aug. 30,	1940	20.9	2593.1	438,100	95,700	342,400
	Total	- - - - - - - - -		$1,406,100	$321,500	$1,084,600

* Total is $4500 less than actual.

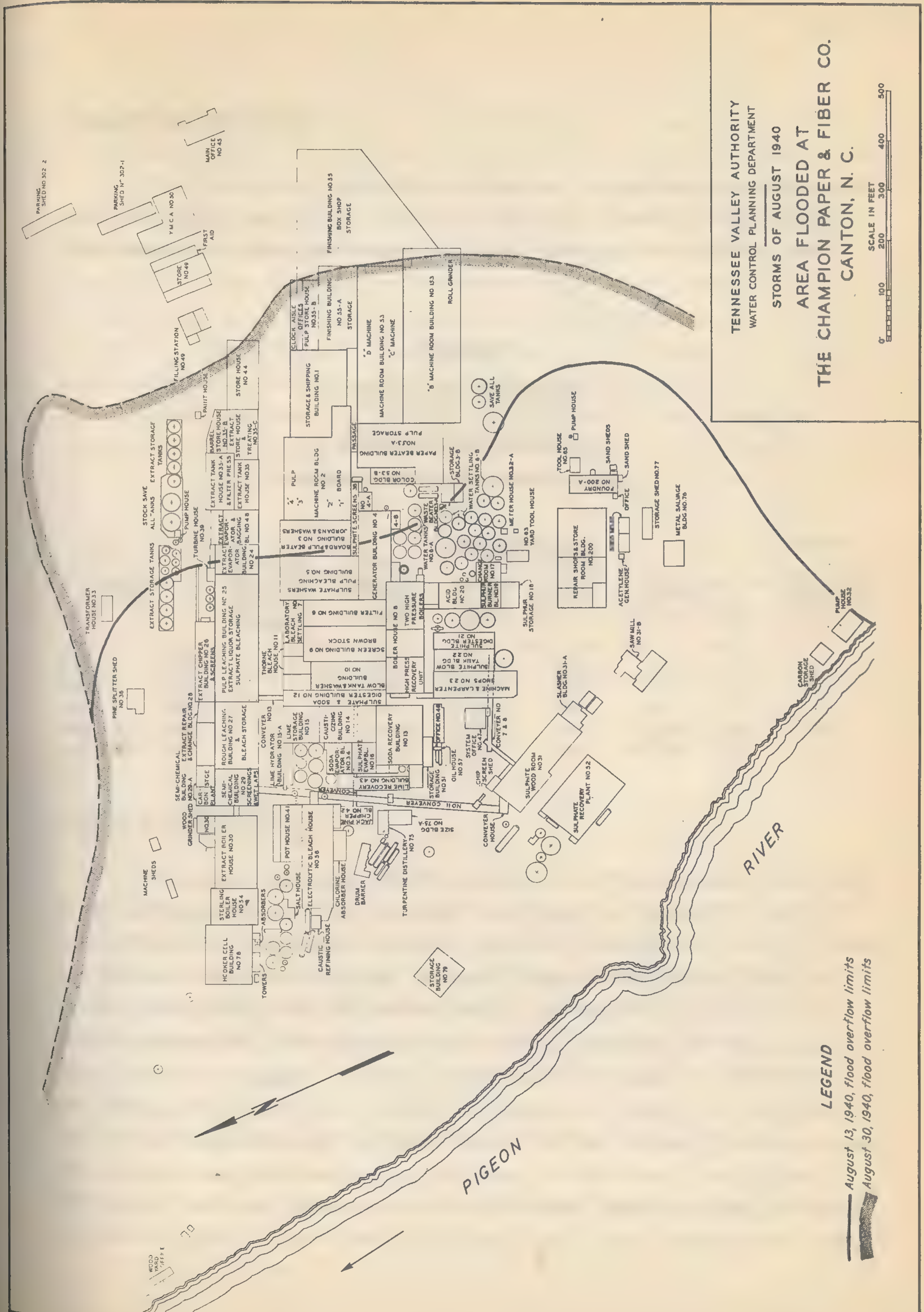
Damaging stage at the gage is 10 feet on the right bank and about 18 feet on the left bank.



TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

STORMS OF AUGUST 1940

AREA FLOODED AT CANTON, N. C.


TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT
STORMS OF AUGUST 1940
AREA FLOODED AT
THE CHAMPION PAPER & FIBER CO.
CANTON, N. C.
SCALE IN FEET
0 100 200 300 400 500
LEGEND
August 13, 1940, flood overflow limits
August 30, 1940, flood overflow limits
PIGEON
RIVER

Magnitude of Past Floods

On the basis of available information, it has been possible to estimate the runoff data for the floods of July 1876, September 1893, August 1928, August 13, 1940, and August 30, 1940, given in the following table.

TABLE 23

FLOOD FLOW AND RUNOFF

PIGEON RIVER AT CANTON

(Drainage Area 133 Square Miles)

Date	Average Rainfall	Gage Height	Peak Discharge Amount	Peak Discharge Per Sq.Mi.	Runoff		Runoff to Rainfall
	Inches	Feet	c.f.s.	c.f.s.	Ac.Ft.	In.	Percent
June 1876	-	18	25,000	188	-	-	-
Sept. 1893	-	18	25,000	188	-	-	-
Aug. 1928	-	16	20,700	156	-	-	-
Aug. 13, 1940	11.5	18.00	25,100	189	31,200	4.4	38
Aug. 30, 1940	9.2	20.75	31,900	240	22,600	3.2	35

Floods of August 1940

On August 13, 1940, there occurred one of the highest floods ever known on Pigeon River. Only seventeen days later, on August 30, came a second flood 2.7 feet higher at Canton than the first flood. Plate 37 shows the limits of overflow at Canton for both floods. Damages were heavy at Canton, particularly for the second flood. The industrial plant of the Champion Paper and Fibre Company, plate 38, was overflowed by the second flood with large damages to motors, machinery, and stock. In Fibreville and the Highland Park section of Canton, 96 houses were flooded and families forced from their homes by the flood water. In the business section of Canton flooding damaged firms on the right bank of the river. Rural areas throughout the Upper Pigeon River valley suffered damages to corn, tobacco, and potato crops. In the first flood practically every bridge on the East

Fork was washed away. Damages in the second flood were less because much of the crops and improvements in the flooded valley had already been destroyed by the first flood.

The August 14, 1940, flood was a near record flood on East Fork, exceeding the record 1876 flood near Cruso but falling a foot or so under it below that point. On West Fork, the flood was from one to four feet under the 1893 flood except where the new fill of U. S. Highway No. 276 backed up the flood a half mile above the mouth. A 100-foot section of this fill was washed out. Below the forks, the flood exceeds the 1893 crest but fell slightly below the 1876 flood crest. Through Canton the flood crest is nearly the same as the crests of the 1876 and 1893 floods.

The August 30, 1940, flood was less severe than either the 1876, 1928, or August 13, 1940, flood on East Fork but on West Fork it exceeded all others with the possible exception of the 1810-1817 flood and it seems most likely that it exceeded that flood. Below Woodrow and through Canton the flood exceeds by two or three feet any other known flood.

Flood Damages

Table 22 shows the estimated damage that would be caused by repetition of known past floods with development as it was in 1941. The total damages are broken down to show the amount of agricultural damages and of industrial and other damages. The greatest losses from floods occurred in the town of Canton where the Champion Paper and Fibre Company's plant is located. The 1940 floods caused large damages but these floods may be expected to be exceeded in the future. Obviously floods of the magnitude of 1940 or greater would cause very large damages.

Appendix B contains further information on flood damages.

Damages from Flood of Mid-August 1940

This flood was the greatest experienced in recent years prior to the late August flood. Total damages in the Upper Pigeon River watershed

FIGURE 17 — AFTER THE MID-AUGUST 1940 FLOOD ON PIGEON RIVER

Inside the plant of the Champion Paper and Fibre Company at Canton. The late August flood was about 3 feet higher than the flood line shown in the picture. (Asheville Citizen-Times photo)

FIGURE 18 — CANTON STREET FLOODED AUGUST 30, 1940

On Park Street, Canton, North Carolina, business and commercial establishments were flooded by the late August 1940 flood.

are estimated at $177,000, of which $101,000 occurred in the Canton area. The Champion Paper and Fibre Company located in the low flat area along both banks of the river in Canton suffered the heaviest damages anywhere in this watershed. The following is a summary of damages classified by type for this flood.

Industrial	$ 97,250
Commercial	2,500
Domestic	3,700
Municipal	1,950
Highways	30,200
Railroad	100
Utility	200
Agricultural	41,400
Total	$177,300

Damages from Flood of August 30, 1940

This flood was the largest of which there is any knowledge on the Pigeon River at Canton. Damages are estimated at $420,000. The Champion Paper and Fibre Company's plant in Canton was again overflowed with large damages. The following is a summary of damages for the late August flood in the Upper Pigeon River Basin.

Industrial	$270,500
Commercial	21,850
Domestic	17,250
Municipal	9,300
Highways	19,600
Railroads	3,000
Utility	400
Agricultural	78,600
Total	$420,500

Agricultural Damages

Agricultural damages in the two 1940 floods have been estimated to be $130,000. These estimates were made in cooperation with the Haywood County Farm Agents J. C. Lynn and J. L. Reitzel who evaluated all land damage and verified the crop yields of each farmer. In Appendix B is a letter by County

Agent Lynn describing high yields and problems arising from floods that confront the farmers in the Pigeon River Valley. There is also a report by Assistant County Agent Reitzel on land damage resulting from the floods of August 1940.

Especially important in this area is the effect of the prevailing flood hazard on farm practices. As pointed out by Assistant County Agent Reitzel in his report, the cultivated bottoms have high values, ranging from $200 to $800 per acre. Of a little over 1000 cultivated acres in the overflow area, 284 acres of land were either partially or totally damaged, the equivalent of over 190 acres of this land being permanently damaged by the August 1940 floods. Many of the farms are small acreages tended by workers in the Canton and Waynesville industries. Loss of crops upsets the economic balance that carries through periods of industrial shut-downs or reduced working hours.

Flood Protection Plan

Flood damages in the Upper Pigeon River Basin are confined principally to the industrial and commercial property in Canton and to agricultural lands in the valley of the Pigeon River and the East and West Forks upstream. In order to provide flood protection for the agricultural lands, it would be necessary to construct storage reservoirs on the East and West Forks above the agricultural lands which would have sufficient capacity to control the headwater floods and keep this water from overflowing and damaging the farm lands. Preliminary investigations of the watershed of both the East and West Forks indicate that there are no suitable sites for storage reservoirs which would control large floods. The valleys of both of the Forks have steep slopes and are relatively narrow so that the required storage capacity cannot be obtained with dams of moderate height.

Just upstream from Canton there is a site where a dam could be built to create a storage reservoir. A dam at such a location would provide flood control for Canton but would flood the agricultural lands upstream. Such a dam and storage reservoir is not the cheapest way of protecting

FIGURE 19 — FARM LAND ON EAST FORK OF PIGEON RIVER DAMAGED AUGUST 13, 1940

Flood waters destroyed crops, scoured some land and deposited boulders on other land causing serious damages. The black top roadway was also washed away by the flood waters.

Canton. This protection can be obtained at considerably less cost by a levee built along the right bank of the Pigeon River through the flood zone in Canton. Although flood protection does not appear to be feasible for the agricultural lands upstream from Canton, some benefits to these lands could be obtained by channel improvements in the Pigeon River and the East and West Forks.

Protection for the property within the flood zone along the left bank of Pigeon River through Canton has been considered but is not included in either proposed plan because the benefits from such protection are not sufficient to justify the cost. The wood storage yard of the Champion Paper and Fibre Company is below flood levels on the left bank. The development in this area at the present time would not warrant the cost of levee protection. The village of Fibreville is located on a narrow shelf on the left bank of the river. The houses in this section are built too close to the river to permit protection by an earth levee and a concrete levee would be too costly for the benefits that would be derived.

The flood problems of the Upper Pigeon watershed are complex and should be given further study before the final adoption of any plan for construction. It is possible that further study might develop a plan which would include some storage above Canton combined with a levee and channel improvements which would be the best overall flood protection plan.

Levee Through Canton

It is proposed to construct a levee on the right bank of the river through Canton, as shown on the accompanying plate 39. Plate 40 is a profile of the levee location. The levee would be constructed of earth. The levee would begin at the high ground above the Main Street bridge and extend downstream along the river bank, tying in to high ground at the lower end of the Champion Paper and Fibre Company's plant. Where there are now existing bridges, it would not be feasible to change the elevation of these bridges. At the openings in the levee at each such bridge on the right bank, large vertical gates made of structural steel would be required which would be designed to be lowered quickly into position in case of a major flood. The

height to which the levee would be constructed might be varied, depending on the degree of protection desired. For complete protection the levee should be high enough not to be overtopped by the greatest flood that might occur. Such a flood is estimated to be of the order of 69,000 cubic feet per second peak rate at Canton. A levee to provide protection against a flood of this magnitude would be 10 feet higher in crown grade than the flood of late August 1940. The estimated cost is $172,000.

A levee of lesser height could be constructed for less cost and would still provide a large measure of protection although it would not give the complete protection that is desirable for urban property of high value. Such a levee has been designed which would give protection against a flood 5 feet higher than that of late August 1940. Cost of this would be $101,000.

The infrequency of large floods and the small drainage area on the landside of the levees indicate that it would not be necessary to make any provision for pumping the runoff from local rainfall over the levee during the short time that the river would be above flood stage. Existing drains into the river would be equipped with automatic valves which would prevent any water backing into the protected area.

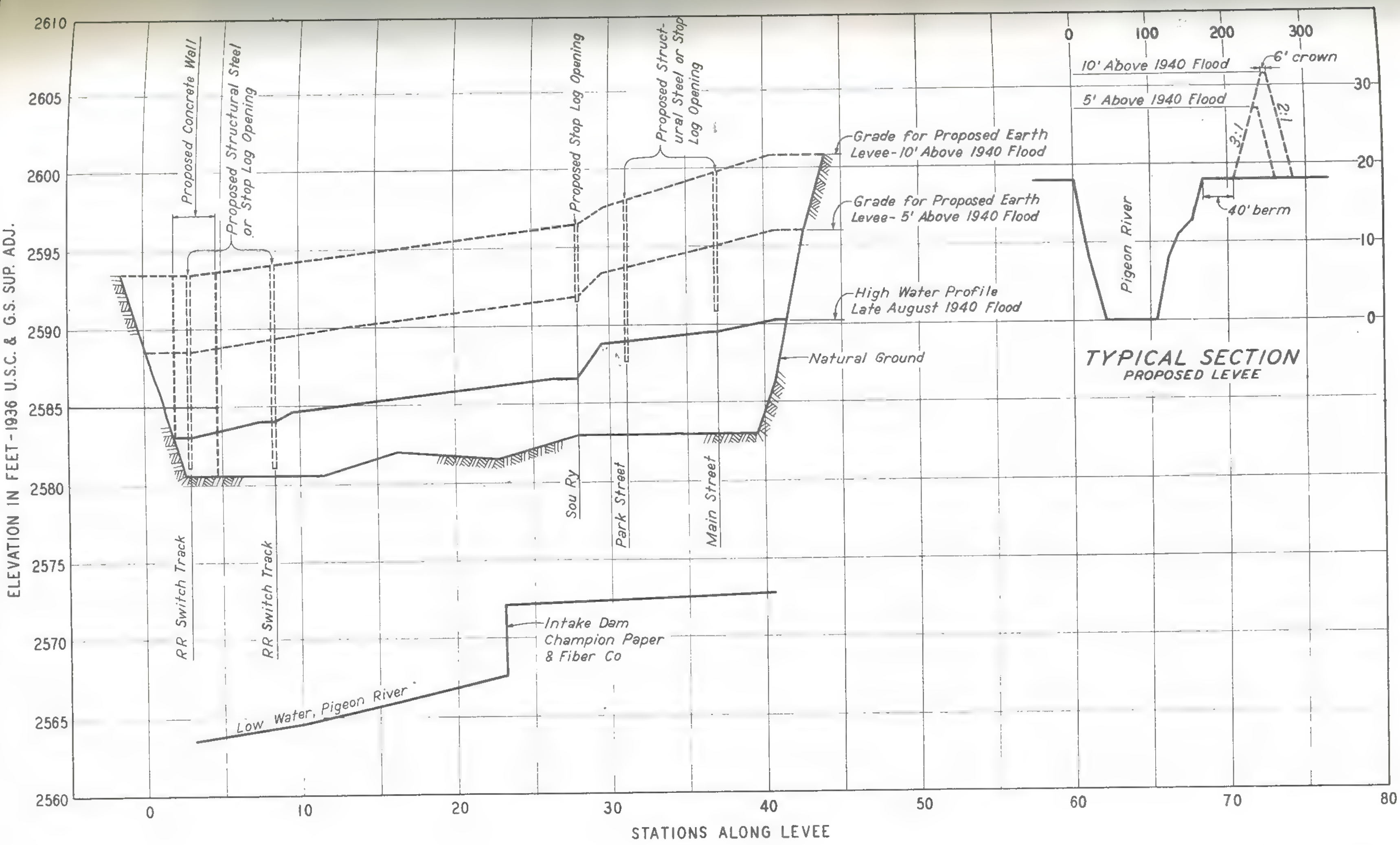
Channel Improvements

The islands in the present channel at Canton should be removed and the Pigeon River and the East and West Forks above Canton should be improved in alignment and capacity in order to give some benefit to the agricultural lands. Places where bank cutting takes place during floods should also be given protection. The extent of improvements to the channel requires detailed study which is beyond the scope of this report. Further study may develop, that by channel improvements it might be possible to reduce somewhat the height of the Canton levee.

Improved Watershed Cover

Along with whatever engineering improvements may ultimately be constructed, it is desirable from the standpoint of water control that the


LEGEND
OVERFLOW LIMITS FLOOD OF AUG 30, 1940
F-96 FLOOR ELEVATION OF BUILDING
W-87 FLOOD WATER ELEVATION
G-70 GROUND ELEVATIONS
R-91 ELEVATION AT BASE OF RAIL
BASE FOR PROPOSED LEVEE 5 FT ABOVE 1940 HIGH WATER
ADDITIONAL BASE FOR PROPOSED LEVEE 10 FT ABOVE 1940 HIGH WATER
CHAMPION PAPER AND FIBER COMPANY
CHAMPION PAPER AND FIBER COMPANY
Pulp Wood Storage
FIBERVILLE
PIGEON
RIVER
Proposed Concrete Wall
Relocate Road Around Levee
Proposed Gate
Relocate Tracks
Relocate Pumping Station
Proposed Gates
Buildings Within Levee Base to be Relocated
To Asheville (U.S. Hwy 19)
Sta 0+0
Sta 43+80
Sta 42+60
TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT
PROPOSED LOCAL PROTECTION WORKS
CANTON NORTH CAROLINA
Scale 100 0 100 200 300



TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

PROFILE
OF
PROPOSED LEVEE
CANTON, NORTH CAROLINA

FIGURE 20 — PIGEON RIVER ATTACKS VALUABLE FARM LANDS

The August 30, 1940, flood cut almost halfway through the higher land which protects the valuable farm land shown on Figure 21. If this bank is not protected, future floods will probably cause the river to break through the narrow neck of high land and cut a new channel through the fertile bottoms shown on Figure 21.

FIGURE 21 — FERTILE BOTTOM LANDS MENACED BY BANK EROSION

This view is looking in the same direction as Figure 20 and is taken from a point about 75 feet behind the man in picture 20. Should the West Fork cut through the hill shown above, this wide and fertile bottom would suffer heavy damages.

program which has been under way for the past few years in improving land use and management in the watershed should be continued. This program is designed to result in improved vegetal cover over the watershed which will be beneficial not only in tending to lower flood heights but in lessening erosion and promoting total water conservation. This is discussed further in a succeeding section of this report.

Estimate of Cost

The following is a condensed estimate of cost of the proposed local improvements at Canton. Appendix E contains more detailed estimates.

	Plan A 10 Feet above 1940	Plan B 5 Feet above 1940
Earth embankment	$ 36,000	$ 20,000
Concrete wall	16,800	6,200
Flood gates at railroads and highways	29,100	7,800
Relocation of structures	26,000	24,000
Drainage outlets	10,000	10,000
Land for right of way and borrow pits	5,000	4,000
Total	122,900	72,000
Contingencies, Engineering and Administration	49,100	29,000
Total Project Cost	$172,000	$101,000

Degree of Protection Provided

Two different degrees of protection would be provided by the two plans: one complete protection; the other partial. However, no flood, of which there is any knowledge, would have overtopped the levee if constructed 5 feet above 1940 flood level. As a matter of fact, this levee would provide protection against a flood about 5 feet higher than any which is known to have occurred in the past 130 years. Engineering knowledge cannot state with certainty that a levee 5 feet above the 1940 flood would ever be overflowed but the possibility of overflow would exist. If the partial plan of

protection should ever be constructed through Canton, then proper means of permanent notification to all future inhabitants of the town should be taken in order to warn them against a false sense of security from overflow during those large floods which might occur.

The local protection works at Canton would have no effect on the agricultural lands.

Benefits

The flood losses in Canton during the late August 1940 flood were more than three times the cost of the local protection works for protection against a flood 5 feet higher. Total losses in 1940 for the two floods were nearly five times the cost of these local protection works. For the plan to provide protection against a flood 10 feet higher than the late August 1940 flood, the cost would be approximately one-half of the late August 1940 flood losses and slightly more than a third of those for both 1940 floods. The tangible benefits from local protection works in Canton are considerably in excess of the cost of the works necessary to provide protection, as measured by the potential losses that would result from one large flood.

Without a detailed study of the Pigeon River and the East and West Forks above Canton, it is not possible to evaluate the benefits that might be received by the agricultural lands in that region from channel improvements. The provision of somewhat greater channel capacity for flood runoff coupled with a better alignment of channel and protection of eroding bends would decrease the possibility of land damage during future floods.

2. LOWER PIGEON RIVER

From a few miles below Canton to near the mouth of the river at Newport the Pigeon River flows through a narrow gorge and damages from floods are negligible. Downstream from Newport between the town and the mouth of the river in the French Broad the valley along the river widens out and

contains some excellent agricultural land, the greater part of which is devoted to truck crops. Damages in this reach below Newport in the two 1940 floods amounted to about $57,000. The accompanying table 24 gives the estimated flood damages for the Lower Pigeon River Basin for repetition of past floods with development conditions the same as for 1941. This table separates damages above Newport and below Newport. Truck crops in the Newport area are grown by or for sale to large canning companies which is a quite different situation than the truck crops which are grown in the Upper French Broad region. Crops there are grown for the fresh produce market and the returns per acre for that type of market, while subject to fluctuations, are generally higher than for the canning market.

The plans for flood protection in the Upper French Broad region would be of some benefit to the lands along the Lower Pigeon because of the reduction of backwater flooding the French Broad. None of the work proposed on the Pigeon River itself would have any effect on the situation of the Lower Pigeon River lands.

TABLE 24

ESTIMATED FLOOD DAMAGES LOWER PIGEON RIVER BASIN

CAUSED BY REPETITION OF PAST FLOODS

Development in Flood Zone is Considered to be the Same as in 1941

Flood		Gage Height*	Total Flood Damage	Damage Above Newport	Damage Newport and Below
	1810	18.0	$ 47,500	$ 6,650	$ 40,850
March	1867	21.5	62,400	11,120	51,280
June	1876	21.0	62,400	11,120	51,280
	1885	16.0	20,650	4,040	16,610
September	1893	15.0	16,750	3,240	13,510
February	1902	21.3	62,400	11,120	51,280
March	1917	14.4	13,250	2,660	10,590
April	1920	17.0	46,800	6,290	40,510
August	1928	12.4	5,250	940	4,310
January	1936	13.9	11,400	2,380	9,020
March	1936	12.6	5,250	940	4,310
April	1936	13.7	11,400	2,380	9,020
August 13,	1940	16.0	20,650	4,040	16,610
August 30,	1940	17.3	46,800/	6,290	40,510
Total (1)	1810-1940		$432,900	$73,210	$359,690
(2)	1867-1940		$385,400	$66,560	$318,840
(1) Length of Period 131 Years (1810-1940)					
Average Annual Flood Damage			$3,300	$560	$2,740
(2) Length of Period 74 Years (1867-1940)					
Average Annual Flood Damage			$5,200	$900	$4,300

* Newport gage.

/ Estimate based on flood of same extent as August 30, 1940, independent of damage caused by preceding flood such as occurred on August 13, 1940.

VIII. LAND USE EFFECTS ON FLOOD CONTROL AND TOTAL WATER CONSERVATION

The flood problem of the upper French Broad Region may be resolved into two parts. The first is concerned with engineering structures such as dams, levees, and channel improvements designed to store, restrain, and control flood waters after they have run off the land. The second part has to do with changes in vegetal cover on the land which may be brought about by improved land use practices and management and which will have a beneficial effect by increasing the infiltration of rain water into the ground and by storage of more water in the ground with consequent proportional reduction in the amount of water than runs off over the surface. Regarding the latter phase of the problem, investigations have been made with the objective of determining the results that can be accomplished by improved land use and land management practices for flood control, for total water conservation, and for reduction of erosion.

General Plan of Work

The accomplishment of the desired objective involves a study of the entire region in its present condition with regard to vegetal cover and the types of existing cover and land use. The present land uses must be correlated by engineering methods with the rainfall and stream flow for past floods in order to establish characteristics for each of the parts of the watershed which will be needed in studying the changes that can be brought about in stream flow by improvements in land use. A vital part of this study is the planning of future land use, outlining what can be done in twenty years or less to change cover conditions so that more water will infiltrate into the ground and store there for consumptive crop use and return flow to streams more evenly dsitributed throughout the year.

Cooperating Sciences

The problem is one which involves agriculture, forestry, and hydrology, and a determination of the effects of improved land use on flood control and water conservation can best be determined by cooperative

and integrated study by scientists in those fields. Such cooperative investigation has been the method of attack.

The Agricultural Relations Department of the Tennessee Valley Authority requested the North Carolina State College of Agriculture to carry out the agricultural surveys and investigations. The Tennessee Valley Authority Forestry Relations Department has made the forest surveys and investigations. The Hydraulic Data Division of the Authority has made the engineering studies.

The North Carolina State College of Agriculture has made strip surveys at a number of places throughout the upper French Broad watershed, has studied the improvements which have been brought about during the past five years on 100 Unit Test Demonstration Farms in the area, has classified all farm lands, and has made plans for future land use for farm lands in the entire watershed.

The Forestry Relations Department has surveyed and classified all the forest lands in the watershed and has measured the areas of open and forested lands throughout the watershed. This Department has also made plans for future forest use.

The Hydraulic Data Division has evaluated the various parts of the watershed from a hydrologic standpoint and has correlated land use with rainfall and stream flow, utilizing the data furnished by the agriculturists and foresters. Using the improved land use patterns furnished by the North Carolina State College and the Forestry Relations Department, the 1940 and 1916 floods have been studied to determine the effects of land use changes in lowering flood heights and in total conservation of water.

The Appalachian Forest Experiment Station and the Agricultural Engineering Department of the Virginia Polytechnic Institute have both cooperated in this study by making available the results of hydrologic measurements on experimental watersheds.

Adequacy of Data

A completely comprehensive study of land use as related to flood control, water conservation, and soil erosion for such a large watershed as that of the upper French Broad, which includes 1858 square miles, would require considerably more data than has been available. For the 1916 flood, records of rainfall and stream flow are far less plentiful than would be desired. For the 1940 floods, stream flow and rainfall information are generally adequate. Infiltration data for the watershed--that is the information on the capacity of various parts of the watershed to absorb rainfall--is meager. Accurate experimental data have been obtained only at the Appalachian Forest Experiment Station near Asheville. While this is invaluable, it must be recognized that the differences in soil and cover characteristics throughout the watershed are such that much more data of this type is needed for a thorough and exact investigation. The available infiltration data has had to be adjusted and correlated with stream flow and rainfall to provide infiltration data for the various sub-areas into which the entire watershed has been divided. The results given in this report should, therefore, be considered as largely indicative of trends rather than as absolute values.

General Conclusions

The results of the engineering investigations, utilizing land use classifications and information furnished by the agriculturists and foresters, lead to the following conclusions:

1. Improved land use management and practices will produce definite beneficial effects in flood height reduction and water conservation.

2. The effect is greater on ordinary floods of common frequency than on great floods of rare occurrence.

3. From the standpoint of total water conservation, improved land use in most watersheds can reduce surface runoff during the growing season of an average rainfall year to a relatively small amount, thus storing more water underground for consumptive use of crops and for regulation of stream flow.

4. Benefits from agricultural cover improvements where these are suited to the land are achieved more rapidly than from forestation.

5. The effect of forest lands is more uniform throughout the year than that of agricultural crops but this effect might be minimized if a satisfactory growth of winter crops can be developed.

6. The effect of the proposed programs of land use improvement in twenty years on reduction of flood heights in the French Broad area are as follows for the floods noted:

Location	Flood of July 1916 Feet	Flood of Mid-August 1940 Feet	Flood of Late August 1940 Feet
French Broad at Rosman	0.6 - 1.0	0.5 - 0.7	0.3 - 0.6
Davidson River	1.0 - 1.2	0.9 - 1.1	0.7 - 0.8
Mills River	2.2 - 3.2	1.5 - 2.0	0.9 - 1.2
Swannanoa	1.4 - 2.1	1.0 - 1.4	0.9 - 1.3
Ivy	2.9 - 4.1	1.1 - 1.5	1.6 - 2.2
Pigeon	---	2.0 - 2.7	1.4 - 1.9
French Broad at Asheville	1.0 - 1.6	1.0 - 1.6	0.7 - 1.4
French Broad at Marshall	0.4 - 0.7	1.4 - 2.2	3.7 - 5.2

7. In the design of engineering works for complete flood protection, the beneficial effects of land use changes are positive, if they can be definitely anticipated, and will permit some reduction in the design of the engineering works and will increase the factor of safety of those works as time goes on.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

UPPER FRENCH BROAD AREA
SHOWING
WATERSHED SUB-DIVISIONS

Land Classification and Surveys

A classification of land use, based on cover and soil was developed in conferences between the various specialists who were concerned with the problem of land improvement and its effect on stream flow. This classification was used in all phases of the study from surveys of present and estimates of future land use to the determination of experimental infiltration rates, and the application of these data to the areas under study.

All land was considered to be in one of the three broad groups: forest, pasture, or cultivated, depending upon use. Each of these groups was subdivided into classes from good to poor depending upon management as exhibited by recognizable qualities of the soil and cover. The position of an area within these classes, and within the groups is intended to be a measure of ability to infiltrate rainfall. The complete description of the land classification groups as used in the field surveys is given in Appendix F.

Sub-Watersheds

For study purposes, the watershed was divided into the 17 sub-watersheds shown on plate 41. Wherever possible, the areas were so laid out that there would be a stream gaging station at the downstream boundary of the sub-watershed.

Infiltration

One of the most important elements in the evaluation of the effect of land and land use on storm runoff is the capacity of the land to absorb or infiltrate rainfall. For the purpose of this investigation, the term "infiltration rate" refers to the average rate of infiltration which is derived by considering an entire storm as a unit. This rate is computed by determining the rate at which the volume of rainfall occurring at higher intensities is just equal to the volume of surface runoff. Although actually infiltration rate varies throughout a storm, the use of the

average rate in this study is justified because the length of storms studied is sufficient so that the average rate may be used without serious error.

Experimentally derived infiltration rates were determined from data collected at the Bent Creek Experiment Station of the Appalachian Forest Experiment Station and the Blacksburg Experiment Station operated by Virginia Agricultural Experiment Station. The experimentally derived rates were used to obtain theoretical infiltration rates for selected unit areas in the French Broad watershed where regular stream gaging stations measure the stream flow. Six areas were selected and infiltration rates computed for both the winter and summer seasons. The floods of April 1936 were used for the winter season and those of August 1940 for the summer season. After a careful consideration of the experimental rates and the observed rates for the area, the experimental rates were reduced by 20 percent and the revised rates were used as applying to the 11 classes of land in the hydrologic studies.

Hydrologic Determinations

As a basis for calculations to determine the influence of improved land use on stream flow, a check was first made through the river system, using the known facts of rainfall and stream flow for past storms. In this case, the mid-August 1940 storm was used. Storage curves for the reaches of the French Broad into which the river was divided were developed. Hydrographs of flow were determined at the lower end of each reach, these being separated into surface runoff and ground-water runoff for the floods being studied. In estimating the effect of improved land use, calculations are made which reduce the surface runoff in proportion to the changes to be brought about by land use. These same changes also increase somewhat the ground-water runoff. In this way, determinations were made of the effect of the improved land use for each of the sub-areas into which the watershed was divided and also for the ends of the four river reaches studied.

Unit Test Demonstration Farms

A study of 100 Unit Test Demonstration Farms in the French Broad area was made by the North Carolina State College Extension Service, and a land classification for 1935 and another for 1941 were determined. This classification showed the changes in land use and character cover on these demonstration farms which were scattered throughout the basin. Computations were made to show the changes in infiltration rates which have occurred on these farms during the five-year period.

The effect of the changes in infiltration rates on runoff for the two August 1940 storms were computed and are given in Appendix F. These figures show that, as a result of the changes which have taken place, surface runoff during these storms was reduced by the improvements in cover. The reduction was more noticeable in the growing season than in the dormant season.

Improved Land Use Programs

The North Carolina State College Extension Service and the Forestry Relations Department of the Tennessee Valley Authority developed programs for land use improvement for future periods for open lands and forest lands, respectively. Two programs were made, the conditions for which were established by Mr. Lee of the North Carolina State College. One is referred to as the "possible program" which is based on maximum improvement of agricultural land use practices. The second is the "probable program" and assumes less intense development and one which might be expected would be accomplished practically. As a concrete measure of what might be accomplished by land use changes, the two August 1940 and the July 1916 floods have been used in the hydrologic studies to determine the benefits in flood height reduction that could have been accomplished by each program during each of these floods. The results of these studies are given in Appendix F. Plate 42 shows the reduction which would have been obtained on the French Broad at Asheville and on Ivy River near Marshall for the two land use programs for the mid-August and late August floods, respectively.

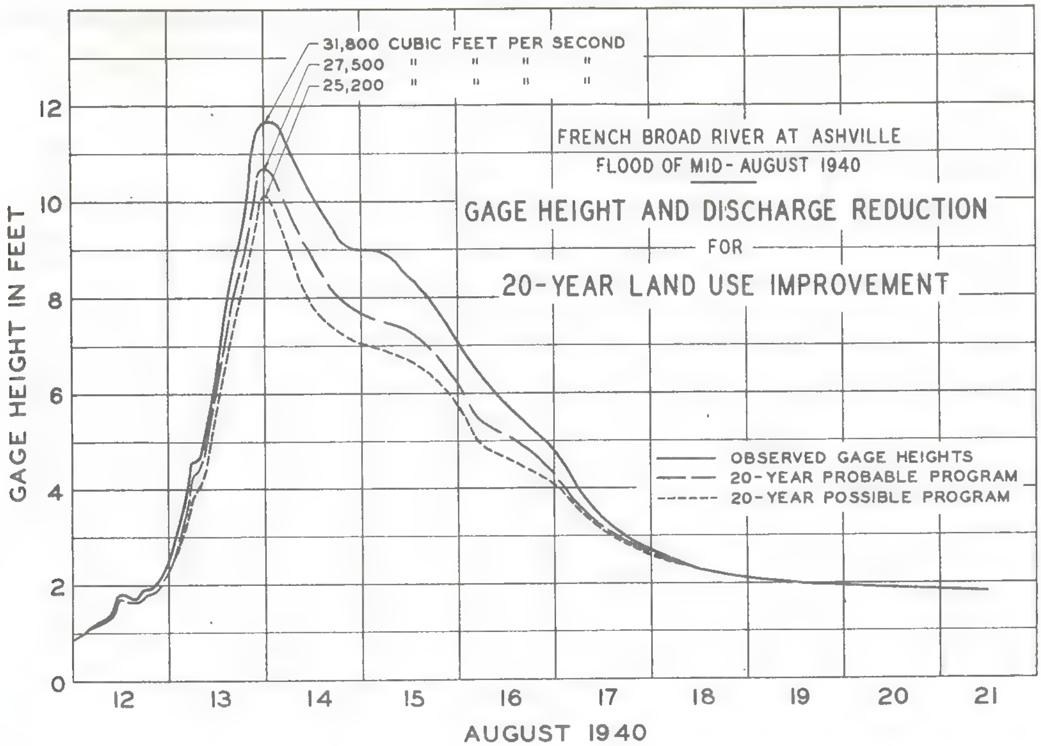
The July 1916 flood was also investigated to determine the effect that improved land use would have on such a record flood. A summary of the investigations made of this flood is given in Appendix F. The effect of the programs for improved land use in reducing the flood height at Asheville was found to be one foot and 1.6 feet for the "probable" and "possible" programs.

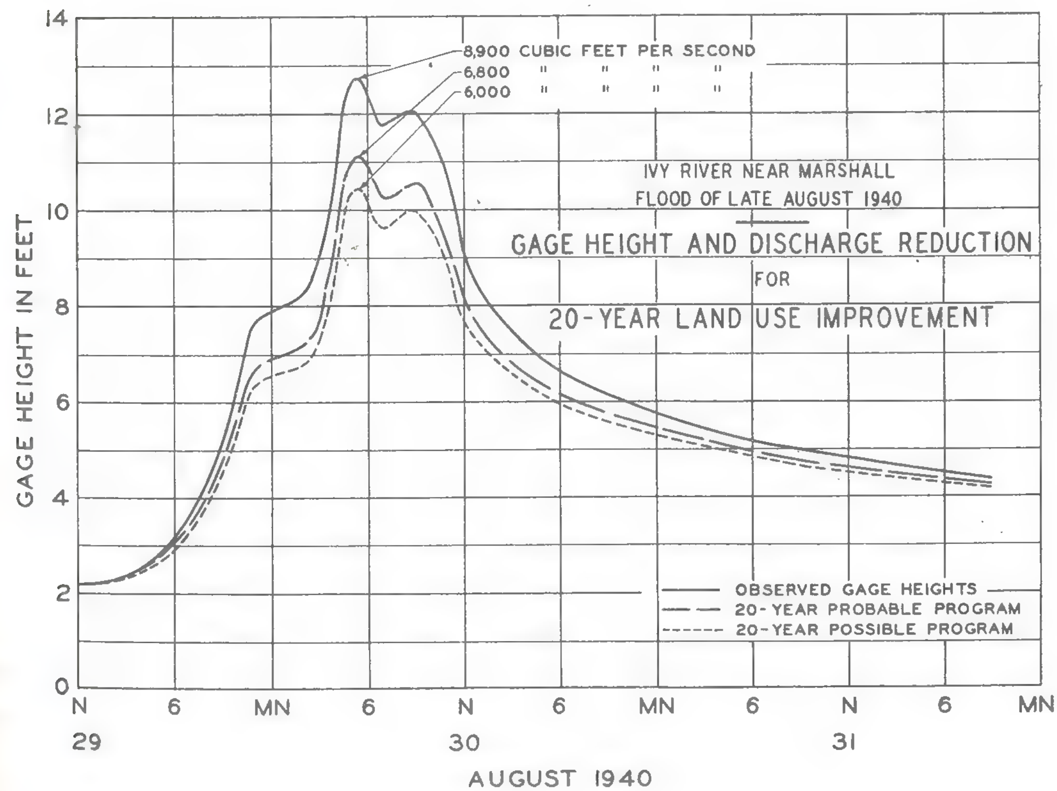
Total Water Conservation

A study was made of the Pigeon River West Fork Demonstration Farms to determine the effect of improved land use and improved cover on the rainfall of an average growing season from May through September. The rainfall during such a period is 25 inches for the five months. The changes between 1935 and 1941 in the demonstration farms indicate that surface runoff would be reduced from 2.3 to 1.7 inches, a reduction of about 25 percent. This is the change over a six-year period, and is not the ultimate that can be attained. During a great storm, such as occurred on the Pigeon River in 1940, the rates of rainfall are so large that infiltration rates for even the best operated land would be exceeded and surface runoff would occur. In such cases, infiltration rate improvement and better land usage supplement engineering measures that would be necessary to control the large amount of flood runoff. The large floods only occur at long intervals of time but the average season is one that may be expected regularly. Because this is the case, it is important to control ordinary growing season runoff on the land by improved land use management and vegetal cover so that surface runoff is reduced to a minimum.

Reduction in Soil Erosion

Reducing the amount of water that runs off over the ground surface also reduces the amount of soil erosion. The growing season is the time of season when erosion is the greatest so that improvement of cover which will prevent soil erosion is important. With surface erosion reduced there will be less silt in the streams than there is now.





TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

TYPICAL
LAND USE IMPROVEMENTS CHARTS

Relation of Improved Land Use to Engineering Construction

The evaluation of the extent to which land use changes may be reflected in the engineering works that may be constructed to control floods is difficult and complex. Investigations of the 1940 and 1916 floods have shown the amount of lowering of flood heights that may be expected for those particular floods or similar floods. The question logically follows "What will happen during larger floods, such as those for which the engineering works are designed to control?" This leads to the question of how large a flood must be provided for. That is the question which cannot be answered exactly. It is a matter which calls for the best judgment of flood control engineers based on long years of experience. Independent determinations by able, experienced engineers are likely to vary widely, much more than the effect of land use changes could ever be on such a flood. The science of meteorology is not yet advanced to where it is possible to say with complete certainty and exactness how big a storm may occur over any area. Flood control works must be designed according to the judgment of the engineer as to how large a flood to protect against, and only the experience of centuries will show whether that flood is too big or too little.

Since engineers are not able to fix the maximum size of floods within exact limits, it is extremely difficult to actually take advantage in design of the decreases in runoff that improved land use may bring about. However, it has been definitely worked out in this investigation that there are finite reductions in flood flows and heights, and it is believed that definite recognition of this should be taken in the design of flood control works for the upper French Broad watershed.

As a basis for such recognition, the reduction in flood heights during the July 1916 flood provides a satisfactory measure. This was a great flood at Asheville, the largest ever known at that place and one that can be described as "an extraordinary flood of rare occurrence." Under the 20-year probable program, it has been found that the peak gage height for this flood at Asheville would be reduced one foot. This reduction has been used in the design of engineering works for the protection of Asheville.

It is true that larger floods than 1916 may occur. It is also true that the benefits from improved land use will not stop at the end of twenty years but should continue beyond that time so that the reduction in flood peak height after the expiration of the twenty years would be more than one foot. It seems reasonable to consider that the additional improvements after twenty years will at least compensate for lesser reductions during larger floods than those reductions which might be expected during the twenty-year period. The one-foot reduction, therefore, is to that extent consistent with the occurrence of larger floods than that of 1916.

If engineering works are designed, taking into account a reduction in flood heights and volumes based on improvements in land use, then these improvements in land use become a part of the whole plan for flood protection the same as dams and levees. This means that there must be reasonable assurance that the land use changes and improvements will actually be undertaken and carried out in accordance with the proposed program.

IX. FLOODS ON SMALL WATERSHEDS

In the mountainous valleys in western North Carolina, floods may occur over small stream watersheds of a few square miles in area of such tremendous proportions that entire creek valleys may be destroyed or devastated so that the future utilization of the valley by the inhabitants is gravely menaced. These floods occur in the summertime and are ordinarily the result of thunderstorms of great rainfall intensity. They may, however, be a part of a larger disturbance, such as a tropical hurricane. The summer thunderstorms are likely to happen over any small mountain watershed and there is no way of predicting the probability or the frequency of such storms.

Usually the watersheds where these floods occur are small valleys or coves surrounded with high mountains. In the valley is a normally small stream bordered by not too wide bottom lands. Because of their fertility, the bottom lands are the most valuable lands in the watershed. According to agriculturists, the best farm economy requires a proper balance of bottom land and upland utilization, each for the purposes for which it is best suited.

The large floods which may occur on small watersheds in this region are a menace particularly to the bottom lands. These floods form in the steep mountain headwaters and rush down the mountain sides into the valley, the swift waters sweeping away bridges, destroying crops, cutting across and scouring bottom lands, making new channels, depositing rocks and debris on some of the land, and washing out and eroding roads.

The intense summer storms are often accompanied by huge so-called slides of material from the mountain side. These are not actually true slides in most cases but are the result of a heavy concentration of rainfall over restricted areas of mountain side, usually starting high up on the mountain. A large volume of water is precipitated in a concentrated small area of perhaps 50 feet in diameter. The tremendous force of the water loosens the soil and rocks where it strikes and starts a flow down the

mountain at a high velocity, in some cases approaching 100 feet per second, scouring out material in its path often down to and sometimes into bedrock. Waste from logging operations and trees add to the material as it moves rapidly down the steep slope. The force of the mass of water, boulders, and timber is so great that everything in its path is carried away. Houses built along small mountain side drains where these flows occur are completely carried away, with loss of life of the occupants.

During the heavy rainfall of late August 1940, the headwaters of the West Fork of the Pigeon River above Canton were subjected to the attack of intense concentrated rainfall which resulted in the development of numerous mountain slide flows. Figure 22 is a picture of one of the mountain valleys in the upper Pigeon River watershed which was subjected to the excessively heavy rainfall in August 1940 and shows the resulting development of several slides. In this case, these started near the top of the mountain and followed the general drainage channels into the main draw. The soil mantle and inter-mixed rocks and boulders were scoured out down to the underlying rock.

Tremendous runoff results in these cases. The magnitude of this runoff is difficult to determine because of the high velocity turbulent flow and the solid debris material which is part of the flow. The drainage area for a draw which such a flow may follow is of no significance as the water does not originate from the tributary drainage area but comes from the concentrated spots near the mountain tops where the water is precipitated.

There are other floods which devastate those small watersheds which are not so intense and which are not accompanied by the tremendous mountain flows. Typical of such a flood is one which occurred on Flat Creek near Asheville on July 16, 1941, on the twenty-fifth anniversary of the great flood of 1916. During the afternoon of that date rain with intensities exceeding one inch per hour fell at a number of stations throughout the region. Over an area of about eight square miles in the headwaters of Flat Creek, 10 miles north of Asheville, rainfall between 4:00 p.m. and 5:30 p.m. exceeded four inches. Flat Creek experienced the highest flood

FIGURE 22 — MOUNTAIN VALLEY STRUCK BY HEAVY CONCENTRATED RAINFALL

Intense localized rainfall striking the mountain side erodes down to and sometimes into rock, carrying huge quantities of rocks and debris on to the lower valley lands causing destruction of crops and lands and often resulting in loss of life.

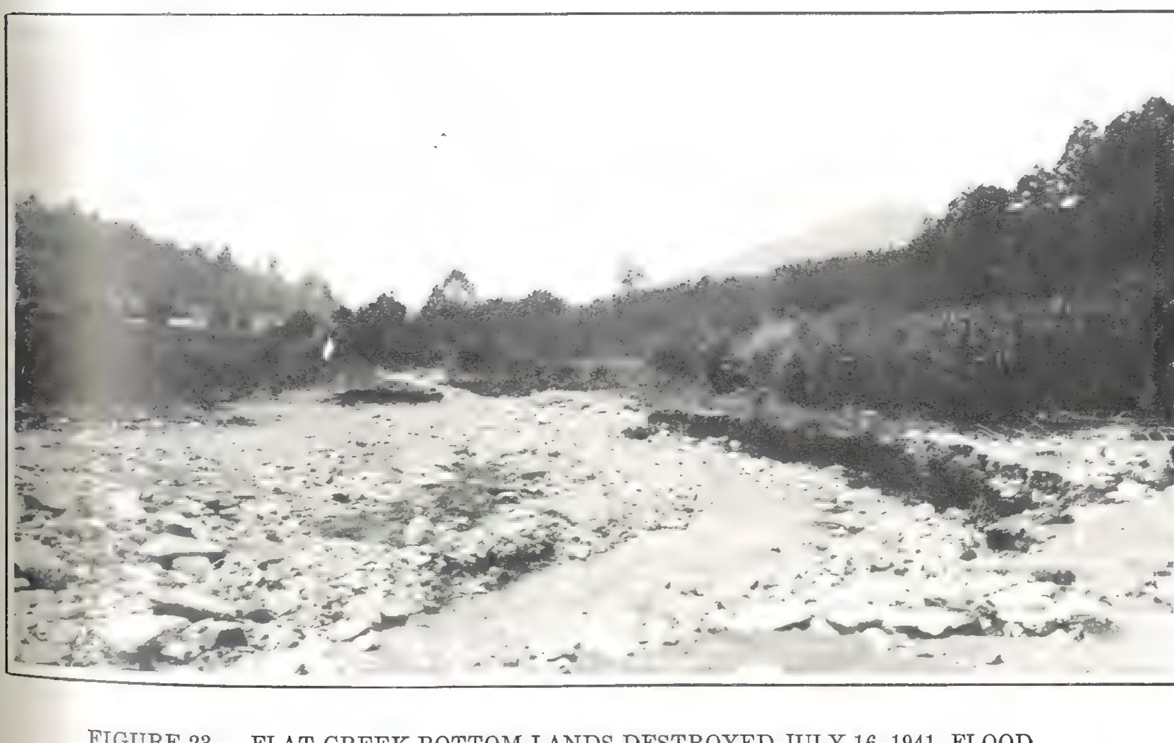


FIGURE 23 — FLAT CREEK BOTTOM LANDS DESTROYED JULY 16, 1941, FLOOD

Intense rainfall on the afternoon of July 16, 1941, resulted in a flood which brought down large masses of rocks and boulders depositing these on the narrow bottom lands. Creek banks eroded and new channels were scoured across cultivated bottoms.

ever known on that stream, even larger than that of July 1916. Damages to crops and improvements in the Flat Creek valley were estimated at about $14,000.

The highest rainfall amount located in the headwaters of Flat Creek was about 7 inches, and the area which received more than 6 inches of rain probably did not exceed one square mile. Mr. James A. Cole who lives near the storm center watched the storm develop and gave the following description which is rather typical for this type of storm in the mountains. Two clouds came together from opposite directions, one from the northeast and the other from the southwest. When they met over the cove in the headwaters of Flat Creek, there was a terrific swirling mass of clouds which was soon obscured by the heavy downpour.

The area having the heaviest rainfall is mountainous and about 75 percent forested. Along the creek are narrow cultivated bottoms. The rainfall was so intense that a large part of it ran off immediately. Flat Creek, ordinarily a small stream under five feet in width, rose rapidly until it was 200 feet wide and 10 feet deep. The velocity was high, resulting in scouring of the land. Fences were washed away, banks eroded, and in several places new channels were formed. Figure 23 is a view of the Flat Creek valley after the flood.

The bottom lands along the creek seldom exceed 100 feet in width but were mostly in cultivation at the time of the flood. Crops were practically a total loss. The estimated loss consisted of 38 acres of corn, 12.5 acres of tobacco, 11.5 acres of wheat, 19 acres of cane and hay, and 2.6 acres of garden vegetables. Highways serving the valley were washed out and bridges carried away. In a number of places, the soil was completely washed away and about 10 acres were a total loss.

What happened in the upper Pigeon River watershed in 1940 and on Flat Creek in 1941 is happening in other small mountain valleys in this region practically every year. When these disastrous storms do occur with destruction of bottom lands, the agricultural economy of the region is upset. For example, on Caney Fork, a tributary of the Tuckasegee River

bordering the upper Pigeon River watershed, a farm economy had been built up over a period of years based on good land use practices of pasturing the slopes along the valley and growing corn and feed crops on the bottom lands. Undisturbed by damaging floods, this valley was known as one of the best in the entire mountain section of western North Carolina. Then came the 1940 flood, leaving in its wake many acres of scoured bottom lands cut up by new stream channels and other areas covered with a deposit of rocks and debris. The area of bottom lands which are available for feed crops has been materially reduced, thereby necessitating adjustments in the farming program for individual farms and for the region as a whole.

The losses due to these small mountain valley floods are not in themselves large by comparison with losses due to great floods on major streams, such as that of the French Broad River at Asheville, but to the farmer making a living out of the land in one of these valleys it is of prime importance. However, control of the small mountain valley floods appears to be practically impossible and such floods must be considered as acts of God for which there is no apparent remedy. The expense of reservoir control would not be justified even if such control were feasible, which in most cases it is not. Likewise, to excavate channels through the small mountain valleys large enough to carry floods would be very costly and in many cases would use up most of the bottom lands which need protection. In the way of preventive measures, the individual farms may protect their lands to some extent from scour, gullying and cutting of new channels by training the streams through individual farms and protecting by timber or rock those bends where large floods might cut across.

The rehabilitation of the small mountain valleys after a flood has passed is important in the preservation of values to as great a degree as possible. After the 1940 floods, the North Carolina State Highway Department performed a considerable amount of work in reconstructing roads and bridges through the flooded valleys which was also of benefit to the lands. Such work supplemented by assistance from county, state, and federal agencies is the best hope for holding to a minimum the permanent damages in small mountain valleys which have experienced one of these devastating floods.

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Tennessee Valley Authority
Water Control Planning Department
Hydraulic Data Division

APPENDIX A

PAST FLOODS

IN

UPPER FRENCH BROAD RIVER BASIN

Knoxville, Tennessee
August 1942

CONTENTS

APPENDIX A

PAST FLOODS IN UPPER FRENCH BROAD RIVER BASIN

FLOOD RESEARCH

An investigation has been made of floods that have occurred on the French Broad River and its principal tributaries covering both the more recent floods which have been recorded and past floods which occurred prior to the systematic collection of stream flow records in the basin. These investigations extend back a maximum of 150 years on the Swannanoa River where the earliest evidence of any flood in the Upper French Broad region was found.

Information regarding floods has been obtained from recorded stream heights where these exist but in order to develop the flood history of the streams in the Upper French Broad watershed, the existing gage records had to be considerably supplemented. This has been done by several methods designed to uncover all the existing data on floods. The Asheville Citizen and Asheville Times and other newspapers in the region have been searched from the beginning of the files. The Asheville newspaper files extend back to 1889 and contain much valuable data on floods on the Swannanoa, French Broad, and other streams in this vicinity. A search has been made in historical books. The book "Asheville and Buncombe County" by F. A. Sondley, LL.D., historian of western North Carolina, contains valuable descriptions of floods. Residents of the French Broad valley and members of the families which originally settled the valley and lived there for long periods were contacted together with other persons having knowledge of floods.

A careful search was made throughout the valley of the main river and its tributaries for high water marks from which to establish profiles for major floods. It was possible to do this satisfactorily for the July 1916 and August 1928 floods as well as for the recent August 1940 floods. The flood of June 1876 was reasonably well developed on most of the streams. The area subject to overflow along the streams was also determined.

As would naturally be expected, information relative to floods in the early years is fragmentary and lacking in detail. This is particularly true for lesser floods which in those days caused little or no damage. For such floods, no records exist either in the memory of living persons, or in any written or printed form, and any long-time compilation of floods must necessarily be incomplete in the matter of lesser floods.

A report giving the results of the investigations on each particular basin was prepared by the Hydraulic Data Division. A list of these reports is given in the bibliography, Appendix G.

A summary of the flood history of each stream is given in the main body of the report relating to each particular stream and is not repeated here. In this Appendix are contained brief descriptions giving the facts for those floods, particularly of early years, which research has developed for each major stream in the Upper French Broad River Basin.

FRENCH BROAD RIVER AT ASHEVILLE

Flood Records

Records of river stages on the French Broad at Asheville have been maintained with some interruptions from 1895 to date. Table 1 gives information concerning the gages which have been maintained at Asheville.

TABLE 1

STREAM FLOW STATIONS
FRENCH BROAD RIVER AT ASHEVILLE

Location	Period	Observed by	Type of Gage
Pearson Bridge	Sept. 1895 - Dec. 1901	USGS	Wire
	Oct. 1922 - Aug. 1930	USGS	Chain
	Aug. 1930 - Date	USGS	Recorder
Old Smith Bridge	March 1903 - July 1916	USWB	Staff
	Nov. 1904 - July 1916	USGS	Chain
	July 1917 - Nov. 1917	USGS & USWB	Staff
New Smith Bridge	Nov. 1917 - Sept. 1922	USGS & USWB	Staff
	Oct. 1922 - Dec. 1933	USWB	Staff
	Jan. 1934 - Date	USWB	Staff

The U. S. Weather Bureau gage has been read once daily throughout. The early U. S. Geological Survey gage was read once daily and U. S. Weather Bureau observations were used from 1903 to October 1922. The U. S. Geological Survey chain gage at Pearson Bridge was read twice daily from October 1922 to August 1930, after which continuous records are available.

Flood Descriptions

With reference to early floods on the French Broad River Sondley's "Asheville And Buncombe County" states:

> Most of the city (Asheville) is built on hills elevated far above the French Broad and Swannanoa Rivers, while parts of the city are much lower than these. For many years, there have occurred, at rare intervals, floods of considerable magnitude in these streams. . . . It is said that there had been a heavy freshet in April 1791 and another in May 1845. On August 28-30, 1852, a freshet had done considerable damage in the valley of these rivers. . . . It has been said that in about 1810 or 1811 there had been a famous freshet on the Swannanoa River, but the injury from it was not great; but this is probably an exaggerated statement. Then in June, 1876, a freshet in both rivers had done much damage, especially in the valley of the French Broad. But on July 16, 1916,

occurred a flood in both rivers which exceeded any of these and caused ravages parts of which are yet to be seen. . . .

April 1791--This flood is reasonably well authenticated for the Swannanoa River but there are no records of how large a flood this was on the French Broad River at Asheville. Such fragmentary evidence as exists indicates that probably this flood resulted from a general storm which covered western North Carolina. In a "Life of David Crockett" written in 1834, there is a reference to a large flood on the Nolichucky River when Crockett was a small boy described as "the second epistle to Noah's fresh." Although the date of this great flood is not particularly definite, it may easily have been the flood of 1791 to which reference is made. This supposition plus the fact that the Swannanoa River was in great flood at that time and that a flood in April is likely to be caused by general rains makes it reasonable to assume that the French Broad at Asheville also was unusually high in April 1791. It is estimated that the river may have been as high as during the flood of July 1916.

June 1876--This is the first big flood for which there is definite evidence as to its exact height and profile. High water marks which have been located show that this flood reached a height of about 18 feet on the present gage. The Signal Service Weather Observer for Asheville describes this flood as follows:

> The most prominent feature of this month was the large freshet on the 15th, 16th, and 17th. The height of the French Broad River in this and the adjacent counties was higher than it is remembered by the oldest inhabitants. Careful investigation elicited the following facts: The river was highest on the 17th noon, after having risen steadily the two days previous. Its maximum height was about 15 feet above common water, and was this height ascertained by a most reliable man who is a builder here in town, has a sawmill near to the river's banks and is perfectly conversant with the stand and change of the river for years. The oldest persons in the county cannot remember such a height of the French Broad, and several of them stated the river to have been 2 feet higher, than ever before. An editorial of one of the town papers dated the last freshet similar to the present one, for the last century, but as the source of this information could not be learned not much reliance can be placed upon this assertion. The tributaries of the French Broad were of course comparatively swollen, but not to such an extent as the present, so for instance the Swannanoa did not reach the height attained in the spring 1875. The damage done is very great, one third to one half of all the crops in the bottom land is destroyed, in many places the river has washed out places of fertile soil 15 to 40 feet wide for 1/4 mile and longer. The bridge over the French Broad 10 miles northwest of Asheville, and to the best information received 4 bridges south (viz. up the river) of town are gone. 1 man has been drowned at Marshall, Madison County.

Floods 1877 to 1915--No important floods occurred during this period although several minor floods did occur. These were in October 1879, June 1892, September 1893, March 1899, May 1901, December 1901, February

1902, January 1906, and August 1910. The three floods of May and December 1901 and February 1902 are of interest because of their occurrence within a period of ten months. The May flood reached a gage height of 11 feet and damaged railroads, industries, and other interests which had by that time sprung up on the Asheville water front. The February flood reached a stage of 11.6, the highest since the 1876 flood, and again caused appreciable losses to the industries and commercial establishments along the river front. Again in August 1910 the French Broad was in flood, reaching approximately the same stage as that of February 1902. Due to continued development damages were correspondingly larger.

<u>July 11 and 16, 1916</u>--On July 11 the French Broad reached a crest stage in Asheville of 10.7 which was sufficiently high to cause considerable damage at Asheville and throughout the Upper French Broad region. This flood had receded only a day or two when it was followed by the greatest flood of definite record at Asheville, that of July 16, 1916. This great flood reached a stage of 23.1 on the U. S. Geological Survey gage and caused tremendous damages at Asheville and throughout western North Carolina. As a result of torrential rainfall, all of the streams in this region rose to flood stages, many of them higher than any previous flood. Damages to railways, highways, industries, agricultural interests, municipalities and others amounted to several million dollars. There was also considerable loss of life.

<u>August 16, 1928</u>--Following two minor floods, one in October 1918 and the other in December 1918, a flood occurred on August 16, 1928, which reached a stage of 13.3 feet on the Asheville gage which is the third highest of record. This flood caused considerable damage on the Asheville water front to industries and commercial establishments.

<u>August 13, 1940</u>--Following 1928 was a period of twelve years during which the French Broad at Asheville did not rise to flood stage. On August 13, 1940, the river rose to a crest stage of 11.7 feet. The rainfall during this storm was so distributed that this flood was of much greater proportions on the headwater tributaries than it was on the main river at Asheville. However, there were some damages on the Asheville water front as a result of this storm.

<u>August 30, 1940</u>--Seventeen days after the first August 1940 flood the French Broad River at Asheville was again in flood, reaching a stage of 12.1 on the gage, slightly higher than the mid-August flood. Lands along the right bank through Asheville were flooded and industries in that area were affected similarly to the first flood.

SWANNANOA RIVER

Flood Records

Actual records of river stages and discharges on the Swannanoa and its tributaries have been maintained principally during recent years. The following table lists the stream flow stations which have been maintained in the basin and the period covered at each station.

TABLE 2

STREAM FLOW STATIONS
SWANNANOA RIVER

Stream	Location	Drainage Area Sq.Miles	Period	Gage
Swannanoa R.	Biltmore	130	Dec. 1920 - Sept. 1926	Staff
			May 1934 - date	Recording
Swannanoa R.	Swannanoa	63	May 1907 - June 1909	Staff
			Jan. 1926 - Sept. 1931	Staff
Beetree Creek	Near Swannanoa	5.46	Feb. 1926 - date	Recording
North Fork	Near Black Mountain	23.8	Jan. 1926 - Jan. 1936	Staff
			Jan. 1936 - date	Recording

Flood Descriptions

April 1791--The earliest flood to which reference has been found occurred in April 1791. Since this occurred 150 years ago when the country was only sparsely settled and stream flow records were not kept, information regarding this flood is naturally scant. Although it has been a long time since the flood, the information concerning it is sufficient to establish it as the greatest flood of which there is any knowledge on the Swannanoa. Four separate references have been found to this flood, at least two of which are independent of the others, which strengthens the facts supporting the flood and its magnitude.

During the days succeeding the great flood of July 1916, Asheville was flood conscious and considerable information concerning past floods appeared in the newspapers. On July 27, 1916, an article was printed in the Asheville Citizen from which the following extract is taken. The Alexanders were among the first families to settle in the Swannanoa valley and Mr. W. J. Alexander who is quoted in the article is a member of that family.

> W. J. Alexander, of Montford Avenue, is the greatest living authority when it comes to 'freshets' in this part of the state. Mr. Alexander was born in 1830, 15 years before the first notable freshet which devastated Buncombe County. His knowledge of the previous freshet was imparted to him by his grandfather, James Alexander, who lived at that time on Beetree, and who told his son of the Swannanoa's rage which has left its marks in the valley to this day--125 years after the river had destroyed all that was in its path.
>
> According to Mr. Alexander, the July freshet . . . was not the highest of any during the past 125 years. The waters of the swollen rivers reached a point 5 feet higher than during any of the previous floods, except that of 125 years ago, and the destruction of property naturally has been incomparably greater, he says.

Several years after the 1916 flood, while on a trip to Washington, D. C., Mr. W. O. Riddick, owner of the Azalea Woodworking Company, Azalea, North Carolina, by chance became acquainted with a man, a New Zealander, who showed him an old journal kept by his great grandfather. In this journal was described a trip this man had made in the year 1800 into the Swannanoa valley, telling of a visit to the Gash place, on the banks of the Swannanoa just below Azalea. Mention is made of a terrible flood nine years before which caused untold damage.

Mr. Riddick states that at the time of the 1916 flood he heard a number of the older residents of the valley talking of another flood 125 years before (1791). This flood was described as having been at least as big, and in several cases as having been 4 to 6 feet higher than the 1916 flood. All of these persons have died since that date.

In "Asheville and Buncombe County," Dr. F. A. Sondley states "It is said that there had been a heavy freshet in April 1791."

The weight of evidence regarding this old flood of 1791 indicates that there was such a flood and that it probably reached a height of about 5 feet higher than that of July 1916.

Other Old Floods--In addition to the great flood of 1791, other large floods are known to have occurred in May 1845, August 1852, February 1875, and June 1876. The flood of May 1845 has been referred to by Mr. W. J. Alexander (Asheville Citizen, July 27, 1916) as "the first notable freshet which devastated Buncombe County." This occurred when Mr. Alexander was 15 years old. Mr. Joe Cheesborough, now 68 years old, recalls having been told by an old Negro slave of a flood on the Swannanoa in his earlier years which "spread from hill to hill." The evidence indicates that the old Negro referred to the flood of 1845.

The Asheville News of September 2, 1852, describes the flood of August 1852 as follows:

> Never in the memory of that wise individual 'the oldest inhabitant' were these mountains so deluged with water as they were last week. Friday of last week will long be remembered as the rainy day. From 10 o'clock Thursday evening until sometime Friday night, without one moment's cessation. The French Broad was higher on Saturday than it has been in many years before, exceeding largely the great flood two years ago. Even the sweet Swannanoa got high and played some wild pranks.

With regard to the flood of February 1875, the North Carolina Citizen for March 4, 1875, states that due to a heavy rain Wednesday evening "the Swannanoa and French Broad Rivers rose so rapidly that persons residing along their banks had to abandon their houses and effects and flee for safety. In many domiciles the water was 3 and 4 feet deep."

The flood of June 1876, ordinarily referred to as the "June freshet," was not as serious on the Swannanoa as on the main French Broad. It was about the same height as the flood of August 30, 1940. Mr. Alexander stated that

this flood ruined all the bottom crops on the Swannanoa and came too late to afford the farmers a chance to replant. The Signal Service Weather Observer for Asheville reports that "the Swannanoa did not reach the height attained in the spring 1875."

May 1901, December 1901, February 1902--These three floods all came within a period of nine months. The highest of the three was the May flood. Newspaper accounts describe the May flood as causing much damage in Biltmore.

> The main line of the Southern has been lifted 15 feet off its bed . . . The track for 150 feet above and below the railroad bridge near Biltmore powerhouse is all in a wash.

Houses in Biltmore were flooded. Highway bridges were swept away. At that time Asheville took its water by pumping from the Swannanoa River. The flood put the plant out of commission for a time, caused breaks in the water lines from the plant, and resulted in a water shortage for several days.

A flood only slightly less severe than the May 1901 flood occurred on December 30, 1901. The Asheville Citizen for December 30, 1901, states:

> Again the French Broad and Swannanoa Rivers have risen out of their banks as a result of a day's storm. All Saturday evening the water began rising and though it did not come within a foot of the recent high water mark, it was up sufficiently to cause alarm and considerable inconvenience in the river sections. The Swannanoa was again over the river drive and the bridge which crosses Haw Creek where it runs into the river was some inches under water.

The third flood in the nine months' period occurred on February 28, 1902, and was less severe than either of the 1901 floods. Newspaper accounts are largely about the French Broad where a more serious rise occurred, but the following mention is made of the flood on the Swannanoa River: "The estimate of the height of the Swannanoa shows that it is not as much by a foot as the last flood and that the French Broad is two feet higher. . ."

July 10 and 16, 1916--The month of July 1916 saw two floods on the Swannanoa, one on July 10 of moderate but damaging proportions and the other on July 16, the greatest flood in recent years. Following the flood of July 10, the Swannanoa fell but was still nearly bankfull when the severe storm of July 15-16, 1916, struck the area. This flood is the greatest which has occurred in recent years and caused large damages along the Swannanoa. This flood is described in the body of this report.

August 1928--This flood, although not as high as the 1916 flood, caused much damage in the Biltmore area which had been developed considerably in the intervening years. Buildings constructed since 1916 within the natural flood plain of the river aggravated flood conditions.

High water marks which define this flood through the reaches of Biltmore, Azalea, and Swannanoa, show the 1928 flood to be from 1 to 9 inches lower than that of August 13, 1940, along the full length of the river.

The August 16, 1928, issue of the Asheville Citizen gives the following account of this flood.

> With highways blocked in all directions and train service suspended between Asheville and Spartanburg and Asheville and Salisbury, Western North Carolina this morning faces one of the worst traffic tieups in recent years as a result of slides and flood waters from streams swollen by nearly 36 hours of continuous rainfall.
>
> . . .
>
> Traffic between Asheville and Biltmore was stopped shortly before midnight when the waters of the flooded Swannanoa flowed across Biltmore Avenue at the northern end of the bridge in such quantity to make it impossible to get a car through.
>
> Heavy damage was reported at all points along the French Broad and Swannanoa as a result of flooded crops, loss to lumber concerns, and flooding of its plants.
>
> . . . Water was 3 feet deep over the Biltmore bottoms at an early hour last night and rising rapidly.
>
> The Sayles Biltmore Bleachery, on the banks of the Swannanoa, reported 15 inches of water over its entire plant early last night. The boiler rooms were flooded.

<u>August 1940</u>--The only times since 1928 that the Swannanoa River has been above flood stage are during the two floods of August 1940. Extremely heavy rainfall over the entire river basin produced the highest flood on the Swannanoa River on August 13, 1940, since the great flood of 1916. Damages from this flood were large and one life was lost. Seventeen days after the flood of August 13, a second flood occurred on the Swannanoa. This was about four feet lower than the first flood and caused considerable damage. These floods are described in the report issued by the Tennessee Valley Authority "Floods of August 1940 In Tennessee River Basin."

CANE CREEK

Flood Records

No stream gaging stations have ever been maintained in the Cane Creek valley and there are no actual records of river stages and discharges available for this stream.

Flood Descriptions

Information on past floods on this stream is very meager.

<u>August 1910</u>--This flood appears to have been the most severe of the early floods for which newspaper accounts were found. The article in the Asheville Gazette News for September 1, 1910, contains the following, under a Hendersonville date line:

. . . The waters of Cane Creek rapidly overflowed the banks and washed away nearly three miles of railroad track. It is said the flood broke all records for the past twenty years. . .

July 1916--This flood was very severe on Cane Creek and was 6 feet higher than any other known flood. Bottom lands were flooded to a considerable depth, water overtopping banks by six to eight feet at many points. All the flat now occupied by the Asheville-Hendersonville Airport was inundated except for a small rise near its center. At the highway and railway crossing at Fletcher the fills were overtopped by 10 to 14 feet. Crops in bottom lands were completely lost and nearly all bridges were swept away by the flood.

August 1928--This flood was the highest in the period 1916 to 1940. The crest agrees closely with the lower of the two August 1940 floods throughout the reach investigated.

August 1940--These floods rank second in importance to the 1916 flood. Except in the upper part of the watershed, the mid-August flood was about a foot higher than that of the late August flood on Cane Creek. These floods are described in detail in the report "Floods of August 1940 In Tennessee River Basin."

MUD CREEK

Flood Records

Stream flow records on Mud Creek are limited to a part of the year 1907 and to the period from 1938 to date. No important floods have been recorded excepting those of August 1940. The existing stream gage now in operation is maintained at the highway crossing near Naples.

Flood Descriptions

June 1876--None of the residents interviewed recalled having heard of the 1876 flood on Mud Creek.

1901 and 1902--Mr. Joe Byers, old resident of the Naples community, recalled that several times prior to 1916 floods occurred in which water flowed over the tracks of the Southern Railway at Naples. He remembered one of these as having been in June of 1902 or 1903. Most likely the flood he referred to occurred in May 1901.

August 1910--The Hendersonville Daily Herald for August 31, 1910, contains the following:

TERRIFIC RAINS CAUSE ENORMOUS PROPERTY LOSS IN SOUTH
HENDERSONVILLE ALMOST ISOLATED FROM OUTSIDE WORLD
HAND OF JUPITER PLUVIUS RESTS HEAVILY UPON THIS COUNTY,
FROM ALL PARTS OF WHICH COME TALES OF WOE AND DISASTER
HEAVIEST DOWNPOUR OF RAIN IN MANY YEARS INFLICTS ENORMOUS
DAMAGE. BRIDGES SWEPT AWAY. ROADS IMPASSABLE.
CROPS PARTLY DESTROYED.

No trains to Asheville and Southbound. They Creep Along at Snail Pace. Tracks in Dangerous Condition.

Every river, branch, stream, and tiny rill in the mountains of western North Carolina today make a new work of swollen, turbulent, property devastating, life devouring, raging torrents, leaving within their wake a loss and damage to property amounting to hundreds and thousands of dollars, the result of incessant downpour of rain since early Monday night. The older citizens of Hendersonville say during their long lives they have never seen such a fall of water for the length of time. There was a constant downpour on today, yesterday, and last night, and the streets were overflowing with water.

The evidence indicates that this flood was of the magnitude of the 1928 flood and that it possibly exceeded it.

July 16, 1916--This flood surpasses all others known in the basin, exceeding the 1928 flood, next highest with the possible exception of the August 1910 flood, by 2-1/2 feet near Hendersonville and by about 6 feet along the lower part of the creek. All bottom lands were inundated; railroads and highways were flooded.

The French Broad Hustler and Western Carolina Democrat for July 17, 1916, states that:

Hendersonville was cut off from communication with the outside world with the exception of a badly crippled telephone and telegraph service.

August 16, 1928--This is the greatest flood that has occurred on Mud Creek since July 1916. High water marks establish it as exceeding the flood of August 13, 1940, by one-half foot near Hendersonville and by two feet near Naples. Railway tracks at Naples were overflowed, highway traffic was stopped at Naples and Hendersonville due to washing out of bridges and flooding of roads. Serious damage to crops resulted.

October 1932--The Hendersonville Times-News of October 17, 1932, contains the following:

With almost 5 inches of rainfall here since 6 p.m., Saturday, and the consequent rising of creeks and streams in this section, thousands of dollars of damage has been done to crops in this county, a survey today revealed.

Mud Creek and other smaller streams in the county were out of their confining banks yesterday and today and thousands of acres of bottom land, mostly planted in corn, are under water. The corn standing in the field in this bottom land is mostly ruined by the high water and much valuable feed and corn has been damaged or entirely ruined by the water.

Mud Creek for the most part is from 10 to 12 feet above its normal level and the French Broad River is also out of its banks and bottom lands along these streams are under water.

August 1940--The two floods of August 1940 were the greatest on Mud Creek since 1932 and possibly since 1928. The August 13, 1940, flood exceeded the flood of August 30, 1940, by one to two feet but was under the 1928 flood a similar amount. Considerable damage to crops resulted. Traffic on U. S. Highway Nos. 25 and 176 was held up for several hours on the 13th when the highway was overflowed.

DAVIDSON RIVER

Flood Records

The following is a list of the stream flow stations and the period of record for each of these in the Davidson River Basin.

TABLE 3

STREAM FLOW STATIONS
DAVIDSON RIVER

Location	Drainage Area Sq.Miles	Period	Gage
Near Avery Creek (Mile 4.4)	31.0	June 1904 - June 1909	Staff
Near N. C. Highway No. 280	40.4	Dec. 1920 - Apr. 1929	Staff
		Apr. 1929 - May 1934	Chain
		May 1934 - date	Recorder

Flood Descriptions

June 1876--High water marks found for this flood indicate it to have been the maximum since earliest settlement of the valley. Evidence on this flood was given by Mr. Robert J. English who was born in 1864, moved into Davidson River valley in 1869, and lived a mile above the mouth of Avery Creek until about 1925 when he moved from the valley. He recalls that old residents always referred to the June flood as the highest they had seen or heard of in their lifetime. Mr. English places the 1916 and 1918 floods somewhat below that of 1876 at his old home. An approximate high water mark found at the Raines' place at Mile 3.5 shows the flood to be only about a foot above the 1918 flood at that location.

July 10 and 16, 1916--Flood profiles show the flood of July 16 to have been slightly lower than the floods of 1918 and 1928 above Mile 1.0. Along the lower mile of river, backwater from the French Broad raised the 1916 flood well above all others.

The Sylvan Valley News, Brevard, North Carolina, for Friday, July 14, 1916, includes the following in describing the rise of July 10 and 11 which preceded the main flood:

> In addition to the French Broad River bottom lands, those on Davidson and Little Rivers, as well as those on the smaller streams, suffered from overflows and even the mountainside farms suffered great damage by washing of soils and injury to crops.

The July 21, 1916, issue of the paper states:

PISGAH FOREST HARD HIT BY FLOODS EARLY SUNDAY

As Davidson River and French Broad began to rise rapidly about 4 o'clock Sunday morning, Pisgah Forest residents near the rivers moved from their homes and, despite rumors of drowning, no lives were lost.

Water was several feet deep over the most of Pisgah Forest. It covered the first floors of some of the stores and residences and it is said to have done considerable damage to furniture, lumber, and the plants of the Carr Lumber Company and the Brevard Tanning Company. The bridge at that point over the French Broad was destroyed.

August 15, 1928--This flood exceeded the 1916 and approximately equalled the 1918 flood above North Carolina Highway No. 280 bridge and exceeded all except the 1916 and 1876 flood below that point. The crest stage at the stream gage on Davidson River near Brevard was 11.8 feet, the maximum of record at the station since its installation. This stage is more than two feet above the crest of the August 13, 1940, flood.

August 1940--Both August 1940 floods were less severe than the floods of 1876, 1916, 1918, and 1928. The August 13, 1940, flood, which crested at 9.22 feet at the Davidson River near Brevard gage, apparently exceeded the 1918 flood near the mouth but was one to two feet below any of these earlier floods at other points. Overflow occurred on the right bank below English Chapel and on the left bank opposite the Ecusta plant, inundating a considerable area to a shallow depth. Several houses were partially flooded or surrounded by the flood waters.

The August 30, 1940, flood, cresting at 7.68 feet at the Davidson River near Brevard gage, did not overtop banks at any point and was some two feet below the August 13 flood at all points.

MILLS RIVER

Flood Records

Actual records of river stages and discharges on Mills River and its tributaries, North Fork and South Fork, have been maintained for the years shown in the following table.

TABLE 4

STREAM FLOW STATIONS
MILLS RIVER

Stream	Location	Drainage Area Sq.Miles	Period	Gage
Mills River	Near Mills River	66.7	Sept.1924 - Sept.1926	Staff
			May 1934 - Date	Recorder
North Fork	Pink Beds	24	June 1904 - June 1909	Staff
South Fork	Sitton	41	June 1904 - June 1909	Staff
			Jan. 1926 - Sept.1926	Staff
	Pink Beds	10	Feb. 1926 - Date	Recorder

Flood Descriptions

June 1876--Mr. W. F. Cathey, a descendant of one of the early families in the Mills River valley, who has lived in the valley himself for 40 years, states that all the old residents he remembers told that the "June Fresh" far surpassed anything known previously. Mr. Edmondson, who has lived on South Fork Mills River near the Mills River Church for 70 years, recalls the 1876 flood and said it washed down great quantities of rock and debris. Large areas of land were scoured out and channels were shifted and widened.

Mr. J. T. Davenport, who has operated the store at North Carolina Highway No. 280 bridge since 1908, states that he was told that the sills for the old store were set a foot above a mark made at the crest of the June flood on a tree at the rear of the store. These sills are still in place at the rear part of the present combination store and residence. The mark had been destroyed before Mr. Davenport bought the store and no check could be made on the accuracy of the story. This was the only reference found to a crest height of the 1876 flood and places the crest at 1-1/2 to 2 feet under the 1916, 1928, and 1940 floods.

February 1902--According to Mr. W. F. Cathey, this flood got into the store at North Carolina Highway No. 280 bridge, indicating that on the lower river, at least, the flood was greater than the 1876 flood. Testimony of Mr. Edmondson and Mr. Pink Smith, living just below Mr. Edmondson on South Fork, place this flood as somewhat under the 1876 flood there although they stated it got out of banks and did some damage to land. No one else interviewed remembered this flood in particular and no definite marks were found.

August 1910--The Daily Herald, Hendersonville, North Carolina, for September 1, 1910, states:

DIRE RUIN AND DEVASTATION IN WAKE OF AWFUL FLOODS
ONE HUNDRED THOUSAND DOLLARS DAMAGE TO HENDERSONVILLE CROPS
BRIDGES DOWN, FRENCH BROAD OVER ITS BANKS, AND ESTIMATED
DAMAGE TO CORN CROP ALONE PLACED AT $50,000

The farmers of Henderson County are poorer by one hundred thousand dollars as a result of the recent floods.

. . .

The Mills River section appears to have been the heaviest sufferer. This is the finest agricultural part of the Henderson County and the crops were all better there this season than during many years past.

A large part of the county is under water, and should it not recede within the next 12 hours, it is believed that almost the entire corn crop will have been ruined.

. . .

July 1916--This flood exceeded any previous flood on Mills River. Mr. Edmondson says it was "about the same" as the June 1876 flood on South Fork, but H. R. Holden, who has lived on South Fork a short distance above the confluence with North Fork for 78 years, says it exceeded the June flood at his place. All the Mills River bottoms were overflowed.

Along the lower part of Mills River overflow depths must have been 4 to 5 feet greater than in 1876 due to the effect of the French Broad. Above North Carolina Highway 280 the flood probably did not surpass the 1876 flood by more than a foot.

August 16, 1928--This flood slightly exceeded the July 1916 flood on Mills River above backwater from the French Broad with a difference in crest height of a few inches at North Carolina Highway No. 280 and one to one and a half feet at the site of the Mills River gaging station, according to information obtained from Mr. S. P. Williamson who witnessed both floods at the latter point.

August 1940--Below the confluence of the North and South Forks of Mills River, the floods of August 1940 exceeded any except those of 1916 and 1928. These floods are described in the report "Floods of August 1940 In Tennessee River Basin."

HOMINY CREEK

Flood Records

The only records of stream stages on Hominy Creek are those which the American Enka Corporation has obtained on the staff gage at its filter plant during the past eleven years. These are useful in the determination of floods in this period. The drainage area of the Hominy Creek at Enka is 86.4 square miles.

Flood Descriptions

June 1876--Mr. J. W. Rutherford, born in 1867, who has lived all his life in Hominy valley and whose grandfather came into the valley around

the year 1800 feels certain this flood was the greatest known up to that time. He remembers the flood and recalls hearing his father say it was worse than any flood ever known since the family had come into the valley.

Mr. C. C. Williams, age about 70, who has worked in the Gaston Mill, below Candler, many years, was able to point out the height of this flood fairly closely in the lower part of the mill. There has been a mill at this site since about 1840 and the June 1876 flood was the highest of any since that date according to the former mill operator. The June 1876 flood was marked on the mill and the mark remained for many years but was lost when a portion of the mill was torn out in remodeling some time later. Mr. Williams recalls this mark as having been about 6 feet above the lower floor of the mill, or about 4 feet below a mark remaining today of the February 28, 1902, flood.

Mr. S. L. Gudger, who has lived all his 70-odd years near Candler, remembers the June Fresh, as this flood was called, and says everyone called it the greatest flood known at Candler up to that time.

February 28, 1902--This flood surpassed the June Fresh of 1876, the highest known previous flood, by four feet at the Gaston Mill and is recalled by residents along the length of the stream as the highest flood prior to the rise of August 30, 1940.

August 31, 1910--This flood is described in the Asheville Gazette-News, September 1, 1910:

> From every section of Western North Carolina details of great damage continue to be brought in. It is hard to estimate the number of bridges that have been washed away. In the Hominy section great damage was done by the floods. The water exceeded by a few inches the record height of 1902. The two iron bridges across Hominy Creek near Candler are safe, but the mill dam of R. J. Gaston's mill is gone while the mill floor is covered with mud. Cole's mill dam at Candler regarded as one of the most substantial dams in this section for its strength went along with the high waters. The mill was not damaged. Numbers of small bridges in the upper Hominy, lower Hominy, Leicester, and Sandymush Sections, as well as Limestone were carried away in the torrents. Crops are badly damaged and the soil washed away in many places. Great damage was done the county roads.

Testimony of residents of the valley are in contradiction with the newspaper accounts regarding the height of the flood. Mr. C. C. Williams states the "August Flood" did not get nearly as high in the Gaston Mill as the "February Flood" (1902). Mr. J. W. Rutherford states definitely that the 1910 flood was not as high at his farm at the "Devil's Dip" above Enka as the February flood.

July 1916--While Asheville was being visited by the greatest flood in its history, Hominy Creek had only a moderate rise. J. W. Rutherford says the creek was out of banks and over low fields but flooding was no worse than in the "ordinary" flood.

August 1928--This flood also was a minor one on Hominy Creek. Asheville newspapers report undermining of some sections of the roadway between Asheville and Canton but makes no other mention of the flood on Hominy Creek. Several residents recall this flood as having topped the creek banks.

August 1940--The mid-August flood in 1940 was of only minor importance on Hominy Creek but the flood of August 29 and 30 resulted in the largest flood known on Hominy Creek. This flood was particularly disastrous because it overflowed the larger part of the American Enka Corporation plant causing tremendous damages. The state highway and railroad through the Hominy Creek valley were also flooded and damaged. The narrow strip of agricultural land bordering the creek was also damaged by the flood.

FRENCH BROAD VALLEY ABOVE ASHEVILLE

Flood Records

Actual records of river stages and discharges on the Upper French Broad River have been obtained at the locations and for the periods shown in Table 5.

TABLE 5

STREAM FLOW STATIONS
FRENCH BROAD RIVER ABOVE ASHEVILLE

Location	Drainage Area Square Miles	Period	Gage
Bent Creek	676	May 1934 - Date	Recorder
Horseshoe	326	Oct. 1904 - Mar. 1906	Staff
Blantyre	296	Dec. 1920 - Mar. 1934	Chain & Staff
		July 1930 - Date	Recorder
Calvert	103	Oct. 1924 - July 1932	Staff
		July 1932 - May 1934	Chain
		May 1934 - Date	Recorder
Rosman	67.9	May 1907 - June 1909	Staff
		Dec. 1935 - July 1937	Wire Weight
		July 1937 - Date	Recorder

Flood Descriptions

June 1876--Mr. R. L. Gash, attorney at Brevard and Transylvania County historian, states that at the time of the 1916 flood in that county the oldest inhabitants said the flood was the greatest they had seen or heard of on the French Broad. The highest flood known previous to 1916 was the "June Freshet" of 1876.

This flood was widespread and extended over much of North Carolina on the east side of the Blue Ridge. The Daily Charlotte Observer for June 17, 20, 21, and 22, 1876, and the South Carolina News for June 24 all contain accounts of this great flood. The Catawba is reported to have been 2 feet higher than any previous high water mark known within a period of 100 years. With regard to the French Broad region, the Charlotte Observer says "almost the entire crop on the French Broad River was destroyed by the recent freshet. There was a 20 ft. rise up to midnight last night but it is falling rapidly this morning. Fields and islands are entirely submerged 5 to 10 feet. Some farmers will lose one-fourth of the crop."

February 1902--This flood caused general disruption of communications in all directions from Asheville but specific data relative to what occurred on the Upper French Broad has not been preserved, except the following item which appeared in the Sylvan Valley News, Brevard, of March 7, 1902.

> March came in with . . . a heavy downpour of rainfall. As a result various streams in the county were soon out of banks, . . . and some bridges had narrow escape. Washouts along the railroads prevented trains running either to Toxaway or Hendersonville from Friday until Tuesday following.

January 1906--From Sylvan Valley News, Friday, January 26, 1906:

> Tuesday morning French Broad River was the highest recorded since the great June Freshet of 30 years ago and those who have been watching the high water marks made at that time tell us that it only lacked 3 or 4 inches of the record made in 1876.
>
> But in the present instance it rained. Roofs that were rainproof heretofore let in water in sluices. The water was hurled into the river valley from the mountain sides with such force that it cut its way through the bottoms, taking all loose soil with it. It was simply a boiling, seething torrent from hill to hill and the damage done to farming lands is incalculable.

This flood is one of few which have occurred during the winter, and is the largest known winter flood.

August 1910--The Sylvan Valley News of September 2, 1910, states:

> . . . The river is reported to be higher than for several years.

The Daily Herald, Hendersonville, for August 31, 1910, says:

> Reports are to the effect that the French Broad has overflowed its banks and that the water is higher than it has been for many decades.

July 10, 1916--The Asheville Citizen, July 11, 1916, reports "Asheville and Western North Carolina are in the grip of the worst flood conditions since the memorable flood of 1910." Also "Mud Creek and the French Broad River were higher at Hendersonville yesterday than at any time in the

last 30 years . . . the many small streams with which Henderson County is lined are out of banks, and the crops are suffering severely."

The Sylvan Valley News, Brevard, Friday, July 14, 1916, reports as follows:

> Transylvania County is emerging from the most destructive overflow it has suffered since the noted June Freshet of 1876.
>
> The plant which furnishes electric power for Brevard and community was put out of commission Saturday night and the town was in darkness Sunday night. . . Several hundred, possibly thousand bushels of rye which had recently been cut and shocked for the threshing machine bowed before the torrents which made of the Transylvania bottoms vast lakes covering thousands of acres of pastures and cultivated lands.
>
> . . .
>
> After the flood gates of heaven opened on Saturday the streams began to rise and on Sunday the French Broad was seen to rise several inches within an hour. . . Hour by hour the streams grew stronger and deeper, broadening over the fertile fields under cultivation until on Monday the river was possibly 15 feet higher than when in its normal course and in some places was nearly two miles wide, covering a vast acreage under cultivation.

July 16, 1916--This flood surpasses all other known floods on the upper French Broad and caused tremendous damages. It is discussed throughout the main text of this report and will not be further described here.

August 16, 1928--The following is from the Brevard News of Friday, August 23, 1928:

> Transylvania County is rapidly recovering from the effects of the floods of last week, when streams of the county left their banks, flooded the highways, covered acres of bottom farm lands, washed bridges and trestles on logging roads away, and had the county isolated for two days. Wednesday of last week was the beginning of the flood conditions when the French Broad River flooded the streets of Rosman and by Thursday morning the high waters had reached a point but little under that which prevailed in the 1916 flood.

October 17, 1932--The Brevard News, October 20, 1932, contains the following:

> Streams, and especially the French Broad River, are out of bounds and bottom lands have been flooded . . . The French Broad had risen to the extent that the Greenville highway was covered with water for a distance about 200 feet and highway No. 28 remained almost impassable due to the overflow of the Horsepasture River.

August 1940--During August 1940 the watershed of the Upper French Broad was visited by two damaging floods, one on the 13th and one on the 30th. These floods are described in detail in the report "Floods of August 1940 in Tennessee River Basin." The early flood produced stages from 1.5 to 2.5 feet higher than the later one, and itself fell short of the August 1928 stages by from two to four feet depending on location. The stages during the August 1940 flood are also lower than such marks as have been found for the floods of 1906 and 1876.

FRENCH BROAD RIVER IN THE VICINITY OF MARSHALL

Flood Records

There are no stream gaging stations on the French Broad River in the vicinity of Marshall. However, at Marshall, the U. S. Weather Bureau has had a staff gage which has been observed intermittently since 1902. This gage was originally established on March 10, 1902, and was discontinued March 15, 1903. The gage was reestablished on December 1, 1917. On August 22, 1934, a chain gage was installed on one of the river bridges. Observations were regularly made daily from July 31, 1919, until April 1, 1934. Since April 1, 1934, regular river gage readings have been discontinued and special observations have been made during high water periods.

Flood Descriptions

June 1876--The following account of this flood and the weather preceding was published in the Daily Charlotte Observer, June 24, 1876, and June 17, 1876.

> THE MOUNTAIN FLOODS - A young gentleman of this city who has just returned from the mountains, whither he went on a drumming expedition, brings a graphic account of the devastation wrought by last weeks floods in "the Switzerland of America." He was water bound up there, and says it seemed as if the waters would move the everlasting hills themselves. Little bit of streams swelled into rivers, and rivers of insignificant width grew a mile wide. Much of the town of Marshall, the county seat of Madison, is built on an island, and the town was nearly all washed away. The jail went away on the bosom of the troubled waters, and had a good deal of company. . . Many of the public roads in the mountains are so filled with debris that they are impassable and will so remain for some time. The young man who brings this information ventures the opinion that there is not now a wild oat in the Black Mountain, all having been washed away by the rain.

> THE WET SPELL - This has been a week of "prodigious dampness." From Monday morning to Thursday night, the sun has been covered continually by clouds which have wept rain at short intervals, until the ground is soft as mush, and mankind and an umbrella have become inseparable. The season has put a period to business of all kinds. The merchants are doing little or nothing, and the farmers find their occupation gone. The rains have interfered

materially with harvesting, and it is feared they will work injury to the abundant wheat crop which is just ready to be garnered. Much of the wheat has already been cut, and is standing in shocks in the field, but a great part yet remains to be harvested and it is harm to this that is most apprehended. Winds have accompanied the rain at times, and much of the wheat and oats is now prostrate upon the ground.

This is worse than April weather, for the aqueous element descends almost unceasingly; whereas, in the "female month," occasional smiles radiate from the face of the sky. Now, one is never safe for a moment without an umbrella, when out door. In other respects, the weather is as little like June as can well be, having been cool enough for a return to flannel during several days just past. "More rain, more rest," the darkies used to say, and if this is true yet, in these post-slavery days, humanity has certainly had time to take a long breath.

February 1902--The Asheville Citizen, March 1, 1902, contains the following regarding this flood.

MARSHALL NEARLY SWEPT AWAY BY FLOOD
DAMAGE TO BUILDINGS AND STOCKS SHOOT UP INTO THOUSANDS OF DOLLARS
NO TRAINS WEST FOR DAYS
MURPHY BRANCH STILL TIED UP, WHILE DAMAGE TO ROADS IS SERIOUS

All communication to points west of Asheville is still cut off. At Marshall it is said the greatest apprehension was caused for fear the entire village would be swept away. The high wall traversed by the railroad tracks, separating the long narrow one street down from the river was out of sight under the flood. A number of buildings were completely washed away and dozens of others undermined from their foundations. Horses, carriages, and other property were carried down with current of the tide. A number of freight cars that were on the switch at the depot were floated away. Freight and express were also carried off by the flood and the people of the little village were almost panic-stricken for fear that all would be lost.

A number of residents of Marshall made their way here on foot and gave an account of the situation in their town. They also reported that the railroad tracks for miles are washed away and that telegraph and telephone wires are strewn all along the river banks.

The damage to the Southern Railway is incalculable. Miles of track in all directions are washed away and a number of valuable bridges gone. It will perhaps be some time before an estimate of the damage done will be known.

The Asheville Citizen, March 4, 1902, contains the following regarding this flood.

LOSS TO TRACK AND BRIDGES ALONE $250,000

Knoxville, March 4. - C. L. Ewing, of the Knoxville Division of the Southern Railway, today announced that the Southern's loss by floods between Morristown and Asheville will aggregate $250,000 to roadbed and bridges alone. The loss by delayed and annulled trains and the cut off of all passenger and freight travel is also very large.

July 1916--This great flood was the maximum which has ever occurred at Marshall.

From the Asheville citizen of July 18, 1916, the following is taken:

MARSHALL HARD HIT BY THE FLOOD; DEATH LIST THREE

The little town of Marshall which is built with its back to the mountains and has the French Broad River for its front yard, has felt the full force and fury of the flood.

The waters exacted a toll of three lives from the town as it swept down the river in all its ungovernable fury, and the tales of sorrow and suffering among the people there are many.

. . .

The property loss is not known, but that it will reach big figures goes as a matter of course. The town has but one street, and that faces directly on the river, and is but a very few feet from its waters. When the flood of Sunday was at its height, eye-witnesses say that the waters swept down that one street like a tidal wave, eight feet and more in height, and that it took everything movable in its path.

There were fifty-eight houses swept away, and with them went the three known to be dead. All the stores were damaged, in many cases the entire contents being taken by the flood. A part of Rector's hotel was torn away and sent crashing against the rocks. The water came onto the steps of the courthouse, and the county jail was isolated.

Drowned in Flood

James Guthrie, and Miss Bridges, his sister-in-law, were in the restaurant owned by Mr. Guthrie when the waters came upon the town. Before they had a chance to escape to the safety of the hills, the frame building was afloat on the very crest of the flood, and the two were seen to fall from the little structure and into the boiling waters of the angry French Broad.

. . .

M. L. Church of Asheville says that both the old and the new bridges at Marshall have gone out. . .

Mr. Church also says that the bridges at Alexander and Tilley's store have gone out. . .

August 1928--This was one of the major floods which have occurred on the Upper French Broad. Damage to Marshall was not great. The Asheville Citizen of August 17, 1928, states as follows:

MANY HOMES FLOODED AT MARSHALL

Marshall, N. C., Aug. 16--Many homes were flooded and business men were moving their stocks of merchandise from ground floors of storehouses today to escape the slowly rising flood waters of the French Broad River which at one today had risen to approximately 8 feet of the high water mark of July 16, 1916.

Several families living in the eastern section of town, the area suffering loss from the flood, had removed their household furniture to higher ground. Part of the state highway was under water for a mile down the river from Marshall and it was believed that part of the roadbed had been undermined. The new $95,000 school building was partly flooded, the basement and first floor being inundated.

. . .

It is probable, officials state, that railroad service into Marshall will be crippled for several days, sections of the track being under from 4 to 6 feet of water.

August 1940--Two floods occurred at Marshall in August 1940. The first on August 14, a small flood, was not important downstream from Asheville. The second, on August 30, was one of the largest floods ever experienced at Marshall. This is discussed in the body of this report. Both floods are described in "Floods of August 1940 In Tennessee River Basin."

IVY RIVER

Flood Records

Actual records of river stages and discharges on the Ivy River have been maintained just above the mouth of the river from May 1934 to date.

Flood Descriptions

June 1876--Old residents of the valley state that this flood exceeded any others since the valley was settled. Mr. Wes Sprinkle, who was born near Parmer Ford in 1860 and has lived there all his life, stated that at the time of the flood the oldest residents then living said it was the highest they had seen or heard of. Mr. Tom Carter, grandson of one of the original settlers in the Barnardsville section, tells a similar story regarding the flood in that vicinity. It appears the June 1876 flood exceeded

the 1916, next highest near Barnardsville, by about a half foot. At Parmer Ford, from elevations Mr. Sprinkle was able to point out, the June 1876 flood exceeded the February 1902, next most severe on the lower river, by about a foot.

February 1902--This flood ranks second in magnitude with the 1876 flood below Forks of Ivy. Mr. Silas Capps, who worked at the Ivy power plant from 1902 to 1929, and Mr. W. H. Fisher, who was chief operator at the plant from about 1912 to its abandonment in 1930, state this flood was the most severe in the history of the plant. . . Mr. Wes Sprinkle describes the flood as being about a foot below the 1876 at Parmer Ford and says it washed away the old bridge at that point and destroyed the mill at Forks of Ivy. Mr. Tom Carter says the flood was around his mother's house but did not reach the height there of the 1916 or two 1940 floods.

July 1916--In the headwaters of the Ivy River this flood ranks next to the maximum 1876 flood. On the lower part of the river, however, the flood was nearly 4 feet lower than that of August 30, 1940. The flood was less severe than several other floods which have occurred on the Ivy River.

April 1927--A flood of major proportions over the lower reach of the river resulted from a severe cloudburst on this date. Silas Capps, former operator at the Ivy power plant, recalls that this flood overtopped the planking on the headwall at the dam, indicating a stage there equal to that of the 1902 flood. Wes Sprinkle, who recalled the other important floods quite clearly,could not remember this flood but said he recalled that several floods since 1916 had reached a height at a large sycamore tree about equal to that of the 1916 flood. Probably this was one of the floods to which he referred. Between Democrat and Parmer Ford it appears this flood was not much under the 1916 flood.

August 1940--Both floods of August 1940 were important on Ivy River but neither was a record flood. Of the two, the August 13, 1940, flood was slightly higher above Forks of Ivy. Below the Forks of Ivy, the August 13 crest was one to three feet below the August 30 flood crest, which surpassed the 1916 crest and approximately equalled the 1902 crest in this reach.

SANDYMUSH CREEK

Flood Records

A reconnaissance investigation was made of this creek because of its importance in connection with the production of floods at Marshall. The flood of August 30, 1940, was apparently the most severe in the history of the basin. The flood of June 1876 was almost as severe as the August 30, 1940, flood. Other floods occur every few years but none of these have approached the two major floods. Because of the incised character of the stream valley, damage from floods is slight, being limited to the loss of some crops in the narrow creek bottoms.

Flood Descriptions

Houses are situated on the steep slopes or on hilltops well above the stream and floods are soon forgotten by most residents. The best authority found on floods in the basin was Hubert Penland whose great-great-grandfather, "Billy" Penland, moved from Ireland to the place below the confluence of North and South Forks of Turkey Creek which is still the Penland home. Hubert Penland remembers his father and grandfather talked about a flood in June 1876 which they said was the highest in the history of the basin. In this flood crops were destroyed the length of the basin and roads were rendered impassable for weeks.

Since that date no floods of major importance had occurred up to August 1940. Mr. Penland recalls that on many occasions bottom lands were flooded by the creeks but said that none of these floods were severe and that they could not be compared with the 1876 flood. He recalls a flood in February many years ago, probably February 1902, in which much ice moved out with the flood, taking out fences throughout the length of the stream. In July 1916, when the French Broad River had its record flood, Sandymush, Turkey, and Newfound Creeks were hardly out of banks, according to Mr. Penland. A similar condition existed in August 1928 when another important flood occurred on the French Broad River.

On August 13, 1940, Sandymush and Turkey Creeks were in moderate flood but little damage occurred except on Little Sandymush Creek where some bottoms were overflowed.

The August 30, 1940, flood was severe in all parts of the basin except Little Sandymush Creek, which, according to Mr. Frank Randall, storekeeper at Canto, North Carolina, was up only slightly more than in the mid-August flood. In other parts of the Sandymush Basin and in all parts of the Newfound and Turkey Creek watersheds, the flood exceeded anything known in the memory of residents. At the Penland place, just below the confluence of the forks on Turkey Creek, the flood exceeded that of June 1876 by about a foot, according to Joe Gudger. Joe, age 78, a Negro born in slavery on the Penland place, has lived there nearly all his life. He remembers the 1876 flood and recalls that it did not quite cover a large rock in the bottom of the rear of the barn lot at the Penland home. The flood of August 30, 1940, overtopped this rock. Testimony of other residents of the basin was to the effect that the flood exceeded the June 1876 flood and was higher than any other in their knowledge.

PIGEON RIVER

Flood Records

Actual records of river stages and discharges on Pigeon River at Canton have been maintained for the years shown in the following table.

TABLE 6

STREAM FLOW RECORDS
PIGEON RIVER AT CANTON, N. C.
(Drainage Area - 133 Sq. Miles)

Period	Gage
May 1907 to June 1909	Staff
December 1928	Staff
January 1929 to date	Recorder

Flood Descriptions

1810 or 1817--Two old residents interviewed mentioned a flood which occurred either in 1810 or 1817. Mr. Will Moore, who has lived below Woodrow since his birth in 1871, stated that his father, who lived the greater part of his life in the Pigeon Basin, told him of hearing a woman, one of the earliest residents, talk of wading through water shoulder deep in getting out of her house which was located just below new U. S. Highway No. 276 on West Fork. Mr. Moore thinks this flood occurred in 1817 and believes it must have been about like the August 30, 1940, flood. Water reached depths up to five feet in the bottom in the vicinity of this point in the late August flood. Mrs. R. E. Sentell recalls that her father-in-law used to talk of this flood as having occurred in 1810. None of the Sentell family lived in the basin at that time so the information must have been given to him by an older resident. From the information obtained, it seems logical that this early flood approached and possibly equalled the August 30, 1940, flood. It is not likely that it exceeded it to any extent.

June 15, 1876--This flood is a maximum on the East Fork except near Cruso. Mr. T. R. Pless, who has lived there since his birth in 1857, remembers some scars left on trees by the flood and states that the August 13, 1940, flood took bark off those trees a foot above the old scars. Mr. Pless said that at the time of the 1876 flood the oldest residents said they had never seen or heard of a flood as great. Below Cruso the flood apparently exceeds all others. Mr. Lon Evans recalls that John Blalock, one of the old settlers on Dix Creek, had a mark of the 1876 flood near the mouth of the creek and that the August 1928 flood was two feet under this mark. This mark has been lost but from what is known of the relation of the 1928 and August 13, 1940, flood, it is probable that the latter flood was exceeded by the June 1876 flood also.

At Woodrow, the flood was known to be on the main floor of the old Blalock Mill. The mill burned down many years ago and it was impossible to establish the flood height at that point.

On the West Fork, the flood was much less severe than the 1893 flood. No marks could be found to establish its relation to later floods.

From Woodrow to Canton, the flood exceeds all others except the August 30, 1940, flood. Through Canton the crest coincides with that of the 1893 and August 13, 1940, floods.

A diary kept by Mr. W. H. Hargrove and now in the possession of his son, Joseph A. Hargrove, contains a description of the flood quoted in part as follows:

> We all planted our crops as usual and on the night of 15th of June had a freshet in Pigeon River which run over much of the bottom lands doing a great deal of damage but still continued to rain until the morning of 17th Saturday and the river came down two feet higher which run over almost all the bottom land on the river and doing more or less damage to near all except my own and a few more.

September 12, 1893--This flood is known on West Fork as the "Sam's Knob Flood" because of the large number of slides said to have occurred on that peak resulting from a rain of cloudburst proportions. Marks obtained for this flood indicate it to be slightly under the August 30, 1940, flood crest on West Fork but to be well above all other floods with the possible exception of the 1810-1817 flood.

On East Fork, Mr. Pless recalls that a sizable flood occurred on this date but that it was nothing like the June 1876 flood there and did not compare with the 1893 on West Fork.

Below Woodrow, the flood was a foot below the August 13, 1940, and about two feet under the 1876 crest. Through Canton these three floods were approximately the same height.

The Asheville Daily Citizen of September 13, 1893, contains the following, the earliest newspaper record of floods on Pigeon River.

FLOOD NEWS

PIGEON RIVER WAY UP - LOGS LOST IN THE TUCKASEGEE

> Canton, N. C., Sept. 12 - Pigeon River was higher last night than at any time since the memorable June Freshet of 1876. No serious damage was done in this locality but farther up the river considerable damage was done. The old store of Captain W. S. Terrell at Sanoma was washed away together with a small quantity of goods, plunder, etc., also a great deal of hay and other farm products, and some stock. His family were, when heard from this morning at nine o'clock, in the upper story of his house, the water being several feet deep over the premises and no way of getting out.

July 16, 1916--This was not a serious rise on the Upper Pigeon. The Asheville Citizen for July 19, 1916, contains the following:

CANTON LITTLE DAMAGED AND CHAMPION FIBRE COMPANY IS UNINJURED

> . . . Pigeon River has been high for the past 10 days but little property damage has been caused. The only damage sustained by the Champion Fibre Company was caused by cutting off of the mill from supplies. (Due to interruptions to rail service.)

No actual shut-down resulted from delays of shipments.

October 1918--The Asheville Citizen for October 26, 1918, states:

NO SERIOUS DAMAGE RESULTED FROM FLOOD
GREATEST RAINFALL IN HISTORY OF WEATHER STATION

What is believed to have been the heaviest rainfall in a 24-hour period is recorded for the 24 hours ending yesterday afternoon. The official figures given out by the local weather department show that in this time a total rainfall of 8.24 inches came down since Thursday afternoon.

. . . Two or three bents in the trestle over the Pigeon River at Canton were washed away. . .

This indicates that in the Upper Pigeon Basin, as in the Davidson River Basin, which adjoins it on the south, the 1918 flood was more severe than the 1916 flood. No information other than this newspaper account was found.

August 16, 1928--This flood was not a serious one on West Fork. On the East Fork the flood was the highest since 1876 and was slightly higher than the August 30, 1940, flood but was not so severe as the flood of August 13, 1940.

Below Woodrow the flood was less severe than the 1876, 1893, or either of the 1940 floods. Through Canton the flood was 1-1/2 to 2 feet under the 1876, 1893, August 13, 1940, group that was high enough to cause considerable damage at the Champion paper plant.

An account in the Canton Enterprise for Friday, August 17, 1928, describes the flood.

CANTON IS VISITED BY HEAVIEST RAIN IN YEARS

SWOLLEN STREAMS GREATLY DAMAGE CROPS AND
PROPERTY IN PATH, HIGHWAYS BLOCKED

The continuous downpour of rain here Wednesday from early morning till night, caused damage to property in this section such as had not been witnessed in a great number of years. Pigeon River began rising at a rapid rate early in the afternoon, and by midnight had swept out a number of small buildings and bridges and damaged crops along its path to a great extent.

Business places and dwellings nearby were much endangered by the rising waters, and in many instances the occupants moved to safety. Cars from the Felmet and Russell Motor Company garages were moved for safe keeping, and a number of the Fibreville residents left on account of their homes being surrounded by water. Fibreville was practically cut off when the iron bridge across the river was swept away and water and sewer connections were put out of service.

Relief was soon given, however, when the water supply was temporarily restored, and plans for a walkway across the river is being made. The main road from Fibreville will be through the Phillipsville section and on to the No. 10 Highway until the bridge is rebuilt.

Champion Fibre Company suffered heavy losses when the trestle across the river used for transportation of wood was swept away, together with a considerable amount of the trackway and pulp wood. Work in many sections of the plant was suspended during the night and did not start until late in the day Thursday.

Considerable damage is reported from the East Fork and Woodrow sections also. The Dick's Creek bridge, two small houses and some outbuildings are said to have been swept away, while other buildings and property are greatly damaged.

Clyde is said to have been completely cut off by the No. 10 Highway being flooded at both ends of the town and a number of the residents nearest the river were forced to move out, taking their stock with them for safe keeping. A number of houses were said to have been flooded also.

August 1940--These floods are described in detail in the report "Floods of August 1940 in Tennessee River Basin." They are also discussed in the body of the report.

Tennessee Valley Authority
Water Control Planning Department
Hydraulic Data Division

APPENDIX B

DAMAGES FROM FLOODS IN FRENCH BROAD RIVER BASIN

Knoxville, Tennessee
August 1942

CONTENTS

APPENDIX B

DAMAGES FROM FLOODS IN FRENCH BROAD RIVER BASIN

The French Broad River above the mouth of the Pigeon River drains an area of 1881 square miles. In the valleys along the main river and its principal tributaries are located not only rich farms but large industrial concerns, commercial establishments, highways, railroads, towns, and cities, all of which are subject to damage from periodic devastating floods.

METHODS OF DAMAGE EVALUATION

The justification of expenditures for flood control in this region depends both on the amount of flood damage which could be prevented and on the benefits resulting. A detailed survey was made to determine the damages resulting from the August 1940 floods. Maps were prepared which defined the overflow area, and every industrial plant and commercial establishment in this area was contacted. Through the splendid cooperation of these concerns detailed damage statements were obtained, many of which were secured direct from the companies' accounts and were of a highly confidential nature as they represented not only the physical loss but the loss of profits, loss of payroll to employees, and other losses sustained during the period of rehabilitation.

In the case of agricultural damages, basic data were furnished by the County Agents and their assistants. The District Agent and other members of the North Carolina State Extension Service reviewed the basis for agricultural damage determinations and gave valuable consulting advice. Detailed maps were used showing the approximate boundary of every farm in the overflow area. Actual contacts were made will all farmers who suffered a loss of crop due to these floods and the acreage, yields, and damage reported by each farmer in the area flooded were recorded.

Domestic damage was secured by means of a house-to-house survey. Contacts were also made with utility, highway, and railroad officials.

Data on damages resulting from past floods were secured during the survey of damage resulting from the August 1940 floods. Major floods of the past such as the July 1916 flood and the August 1928 flood resulted in extensive damage. Many industries, commercial concerns, and farmers located in the area suffered damages in these earlier floods and furnished reliable statements covering their loss from each individual flood. Using this information as a basis, and taking topography, the elevations of plant buildings, and other factors into consideration, estimates of damage were made for the repetition of each major flood of record assuming development of the flood plain as of the present time. Information obtained from newspaper files on damage in past years was helpful in estimating these losses.

Flood Losses

In order to appraise the disastrous results and sometimes heavy cost of floods in the French Broad Valley, investigations were carried out to establish the stage of all major floods of record and to determine the damage which would result from a repetition of these floods at the present time. On some of the tributaries, the earliest flood known occurred in 1791 while in others, due perhaps to the sparsely settled country, the earliest flood of which there is knowledge occurred in 1875. Table 1 gives the damage which would result should the major known floods of the past recur at the present time. This shows not the damages which actually occurred during each particular flood, but the estimated damages that would be caused by repetition of each past flood with development as it was in 1941. This method of estimating damages has been adopted because during the floods of several years past, the settlement and development of the French Broad region had not progressed to its present state. Obviously, actual damages in those cases were considerably less than they would be under present conditions. For the agricultural areas, damages have not been estimated for past floods under the then prevailing conditions of culture because of the difficulties of obtaining accurate data on the area of land cultivated, the crops raised, and the prices of such crops. A better conception of the flood damage situation is given by estimating the losses as they would be for each past flood with developments as they are now.

The total flood damages determined on this basis are $13,599,800 since 1875. Starting in 1791, disastrous floods were recorded on the Swannanoa River, the French Broad at Asheville, the Lower French Broad River, and the Pigeon River. These known floods would increase the total damage to $19,742,000 but doubtless there were other floods in the earlier years between 1791 and 1875 of which there is no record. Inclusion of such floods would materially increase the damage total.

Classified Damages

In the survey of damage resulting from the August 1940 floods, data were secured by various classifications or types of damage such as industrial, commercial, utility, and agricultural. Such detailed information permits an analysis of the total damage to be made readily and also defines the extent of both urban and rural damage. Some of the tributaries are thickly settled and here industries and commercial establishments suffer the major damage. Other tributaries are dominantly agricultural and here the floods result in damage to crops and land over a wide area and affect the lives of many people. Table 2 is a summary of estimated classified flood damages caused by repetition of all major floods of record from 1875 to 1940, inclusive.

Direct damages are the actual physical loss and expenditures for the flood emergency. Indirect losses are caused by interruption of commercial activity, the stopping of the normal earning capacity, and loss of profits of commerce and industry for the duration of the high water and for whatever length of time is needed to clean, rehabilitate, and place a plant in operating condition. A repetition of past floods would cause by far the largest damage to the industries located in the flood plain.

TABLE 1

ESTIMATED FLOOD DAMAGES
FRENCH BROAD RIVER BASIN

Caused by Repetition of Past Floods
With Development As In 1941

Flood	Gage Height Blantyre	Gage Height Asheville	Gage Height Marshall	Amount of Damage
February 1875	17	9		$ 158,900
June 1876	23	18	21	1,881,500
October 17, 1879	19	9		66,400
1885	Pigeon River Basin Only			20,600
June 1892		10		23,000
September 1893	18	9		254,000
July 1896	Hominy Creek Basin Only			2,000
March 15, 1899	17	10		38,900
March 19, 1899	17	9.8		38,900
December 1899	Swannanoa River Basin Only			18,000
October 1900	Hominy Creek Basin Only			1,300
May 1901	20	11	13	264,400
December 1901		9.4	13	100,500
February 1902	19	11.6	21	517,800
July 1905	21			107,900
January 1906	22	8.9		188,200
July 1910	Mud Creek Basin Only			13,100
August 1910	21	11.6	14	285,200
May 23, 1916	17			15,900
July 10, 1916	22	10.7	13	257,400
July 16, 1916	27.2	23.1	24	4,866,200
March 1917	Pigeon River Basin Only			13,300
October 25, 1918	17			26,400
October 29, 1918	20	9		91,800
December 23, 1918		10		23,000
April 1920	Pigeon River Basin Only			46,800
April 1923	Cane Creek Basin Only			7,400
July 1928	Mills River Basin Only			4,200
August 16, 1928	22.90	13.3	16.3	681,300
March 14, 1929	19.20			53,400
October 1932	20.68			136,200
March 5, 1934	17.32			15,900
January 1935	18.29			33,800
June 1935	Hominy Creek Basin Only			1,300
January 1936	Pigeon River Basin Only			11,400
March 1936	Pigeon River Basin Only			5,200
April 1936	18.85			70,600
October 17, 1936	17.43			17,900
January 7, 1937	17.70			33,100
October 20, 1937	18.83			53,400
August 17, 1939	Mud Creek Basin Only			800
August 19, 1939	17.40			15,900
August 13, 1940	21.88	11.7	14.5	772,800
August 30, 1940	19.31	12.1	20.3	945,600 a
Land and Property Devaluation in Asheville and Biltmore				1,418,200
Total				$13,599,800

(a) Actual damages $889,500 greater than amount shown.

Losses to industry and commerce including land and property devaluation would amount to $6,656,900, representing 49 percent of the entire damage. Losses to agriculture would amount to $3,772,400, or 27.7 percent of the total loss. The welfare and livelihood of thousands of people depend on industrial and commercial operations and agriculture, yet in this area 76.7 percent of the total damage would occur to these two fundamental requisites to the life and welfare of the people.

TABLE 2

ESTIMATED CLASSIFIED FLOOD DAMAGES
FRENCH BROAD RIVER BASIN

Caused by Repetition of Past Floods
With Development As In 1941

Type of Damage	Amount	Percent
Industrial	$ 4,806,100	35.5
Commercial	432,600	3.2
Domestic	149,700	1.1
Municipal	186,100	1.3
Highways	831,800	6.1
Railroads	1,865,900	13.7
Utilities	137,000	1.0
Agricultural	3,772,400	27.7
Land and Property Devaluation	1,418,200	10.4
Total	$ 13,599,800	

DAMAGES ON MAIN RIVER REACHES
AND TRIBUTARIES

Each major tributary or reach of the French Broad was surveyed in detail and data on damages resulting from all major floods of record were secured. Some of the tributaries are dominantly agricultural while on others the concentration of industries in the flood plain has resulted in tremendous industrial losses.

Davidson River Basin

The watershed of this stream is about 99 percent forested and flood damage is ordinarily limited to the overflow of bottom lands near the mouth of the river, the washing away of small bridges, and the flooding of roads in the forest area.

With the exception of the Ecusta Paper Plant, the Carr Lumber Company, and small commercial developments with a surrounding low-cost housing area at the town of Pisgah Forest, houses and buildings are located above high water.

On the basis of stages reached by past floods, flood damages have been estimated that would result from a repetition of past floods.

Estimated Flood Damages Caused by Repetition of Past Floods
(Development in Basin Same as in 1941)

Flood	Gate Height*	Total Flood Damage	Damage Above Proposed Dam Site	Damage Below Proposed Dam Site
June 1876	11.9	$ 8,900	$ 1,400	$ 7,500
July 16, 1916	10.3	15,200	350	14,850
October 1918	10.9	2,100	550	1,550
August 15, 1928	11.8	8,900	1,400	7,500
October 22, 1932	10.04	1,800	350	1,450
January 8, 1935	8.80	650	---	650
October 18, 1938	7.85	200	---	200
August 13, 1940	9.22	1,700 a	50	1,650
August 30, 1940	7.68	200	---	200
Total		$ 39,650	$ 4,100	$ 35,550

* At present gage on Davidson River near Brevard, North Carolina.

a Actual damages $15,700.

The damages in the table are those for a repetition of past floods only. However, the occurrence of a flood large enough to top the Ecusta Paper Corporation levee would cause enormous damages to that concern, damages many times the total estimated damages for all past floods on Davidson River.

Classified Damages--Repetition of past floods in this basin would damage industry and agriculture about equally. There would be no damage to utilities.

Type of Damage	Amount	Percent
Industrial	$ 15,200	38.3
Commercial	500	1.3
Domestic	4,150	10.5
Municipal	600	1.5
Highways	3,300	8.3
Railroads	1,900	4.8
Agricultural	14,000	35.3
Total - - - - - - -	$ 39,650	

Mills River Basin

About three-fourths of the Mills River watershed is heavily wooded, but along the lower reaches of the river there are wide fertile bottom lands where crop losses are experienced during floods. There are no industrial or commercial developments. There are no settlements and no railroads in the area. Damages are confined to crop losses and damage to roads.

Estimated Flood Damages Caused by Repetition of Past Floods
(Development in Basin Same as in 1941)

Flood	Gage Height*	Total Flood Damage	Damage Above Proposed Dam Site	Damage Below Proposed Dam Site
June 1876	12.0	$ 16,500	$ 6,300	$ 10,200
May 1901	11.0	8,500	3,650	4,850
February 1902	12.0	16,500	6,300	10,200
January 22, 1906	10.0	4,200	1,600	2,600
August 31, 1910	12.0	16,500	6,300	10,200
July 16, 1916	12.5	31,500	11,150	20,350
October 30, 1918	10.0	4,200	1,600	2,600
July 1928	10.0	4,200	1,600	2,600
August 16, 1928	13.5	30,900	13,400	17,500
August 13, 1940	13.2	23,500	9,850	13,650
August 30, 1940	13.6	28,500	14,850	13,650
Total		$185,000	$ 76,600	$ 108,400

* At present gage on Mills River near town of Mills River.

Classified Damage--At the time of the August 1940 floods this area was used extensively for truck crops. Agricultural damage amounts to 93.1 percent of the total and was exceptionally high due to the type of crops cultivated in the area overflowed. There would be no industrial, commercial, municipal, railroad, or utility damage.

Type of Damage	Amount	Percent
Domestic	$ 200	0.1
Highways	12,500	6.8
Agricultural	172,300	93.1
Total - - - - - - - - -	$185,000	

Mud Creek Basin

Along this stream, wide overflow of bottom lands occurs with each important rise causing heavy damages to crops. In addition to crop losses, there are some damages to roads and bridges, and occasional damage to railroad track. There are no industrial or commercial developments in the overflow area and the farm houses are located above high water.

Estimated Flood Damages Caused by Repetition of Past Floods
(Development in Basin Same as in 1941)

Flood	Gage Heights*	Total Flood Damage	Damage Above Clear Creek	Damage Below Clear Creek
June 1876	15.0	$ 50,500	$ 15,300	$ 35,200
May 1901	13.0	26,500	8,200	18,300
December 1901	12.0	19,700	6,600	13,100
February 1902	12.0	19,700	6,600	13,100
January 22, 1906	10.0	13,100	3,300	9,800
July 1910	10.0	13,100	3,300	9,800
August 1910	15.5	50,500	15,300	35,200
July 10, 1916	15.0	50,500	15,300	35,200
July 16, 1916	21.5	122,000	38,200	83,800
August 16, 1928	14.9	50,500	15,300	35,200
October 16, 1932	13.5	26,500	8,200	18,300
April 6, 1936	9.0	5,750	1,250	4,500
August 19, 1939	8.53	800	200	600
August 13, 1940	13.07	26,500	8,200	18,300
August 30, 1940	11.0	15,700	5,350	10,350
Total		$ 491,350	$ 150,600	$ 340,750

* At Naples Stream Gage.

Classified Damage--Damages in this watershed are confined to crop losses, damage to roads and bridges, and occasional damage to the railway. Agricultural losses amount to 72 percent of the total. There are no industries, commercial establishments, or towns damaged in the area.

Type of Damage	Amount	Percent
Domestic	$ 10,800	2.2
Highways	63,400	12.9
Railroads	61,500	12.5
Utilities	1,100	0.2
Agricultural	354,550	72.2
Total - - - - - - - -	$ 491,350	

Cane Creek Basin

Damages in this watershed are confined to crop losses, damage to roads, to the railroad, and flooding of the airport.

Estimated Flood Damages Caused by Repetition of Past Floods
(Development in Basin Same as In 1941)

Flood	Elevation*	Total Flood Damage	Damage Above Proposed Dam Site	Damage Above Proposed Dam Site
June 1876	2094	23,150	13,850	9,300
September 1893	2093	13,200	7,200	6,000
May 1901	2092	7,400	3,900	3,500
December 1901	2092	7,400	3,900	3,500
February 1902	2092	7,400	3,900	3,500
August 1910	2094	23,150	13,850	9,300
July 16, 1916	2101.5	101,200	29,000	72,200
April 14, 1923	2091.5	7,400	3,900	3,500
August 16, 1928	2093.6	23,150	13,850	9,300
August 13, 1940	2093.6	23,150	13,850	9,300
August 30, 1940	2095.1	25,200	15,300	9,900
Total		$ 261,800	$ 122,500	$ 139,300

* There are no gaging stations on Cane Creek. The mouth of Robinson Creek was selected as a point of comparison for floods.

Classified Damages--The area is dominantly agricultural with all farm homes being located well above high water. There are no industrial or commercial developments in the flood plain other than the new Asheville-Hendersonville Airport. Damages are confined to crop losses, damage to roads, and flooding of the airport. Agricultural losses amount to almost 76 percent of the total loss with the balance distributed as shown.

Type of Damage	Amount	Percent
Commercial	500	0.2
Domestic	6,100	2.3
Highways	21,700	8.3
Railroads	35,100	13.4
Agricultural	198,400	75.8
Total - - - - - - - -	$ 261,800	

Hominy Creek Basin

Ordinary flood damages on Hominy Creek are limited to overflow of narrow bottom lands, to highways and bridges, to the railroad, and to small commercial establishments at Candler. The large industry, the American Enka Corporation, is vulnerable to tremendous damage from large floods.

Estimated Flood Damages Caused by Repetition of Past Floods
(Development in Basin Same as in 1941)

Flood	Elevation*	Total Flood Damage
June 1873	2055	$ 1,000
June 1876	2059	12,000
September 1893	2058	2,000
July 1896	2058+	2,000
October 1900	2056	1,300
May 21, 1901	2058	2,000
February 28, 1902	2061	39,500
August 31, 1910	2060	30,400
July 16, 1916	2055	1,000
August 16, 1928	2055	1,000
June 8, 1935	2056.0	1,300
October 16, 1936	2057.9	2,000
August 13, 1940	2057.9	2,000
August 30, 1940	2061.6	45,500 a
Total		$143,000

* Based on gage at American Enka Corporation plant.

a Estimate based on Enka plant not being overflowed. Actual damage was $921,000.

This table is not a true representation of the flood damages that may be expected on this stream. Although the 1940 flood was the greatest known on Hominy Creek, much greater floods are probable of occurrence. Such floods would overtop the present protection works of the American Enka Corporation and flood the plant. One such flood would cause losses about seven times the total for all floods shown in the table.

Classified Damages--Since the 1940 floods, the Enka Corporation has constructed its own flood protection works which protect against floods slightly greater than that of 1940. The damages to this one large industry from one big flood of a size that may be expected would doubtless exceed the losses in 1940. There are only a few small commercial developments at Candler subject to flooding. All houses are located well above high water. Flood damage is ordinarily limited to the overflow of bottom lands and the washing away of small bridges. Railroads suffer the greatest damage from floods in this basin followed by agriculture as shown by the following table.

Type of Damage	Amount	Percent
Industrial	*	-
Commercial	$ 13,300	9.3
Domestic	3,400	2.4
Highways	16,100	11.2
Railroads	61,200	42.8
Utilities	8,700	6.1
Agricultural	40,300	28.2
Total - - - - - - - -	$ 143,000	

* None for repetition of known past floods against which local protection works at Enka plant are adequate.

Upper French Broad River Basin

The valley of the Upper French Broad River is dominantly agricultural and flood damages are mostly to crops. The largest towns along the river are Rosman and Brevard. The only industries affected by floods are at Rosman. Farm homes in general are located above flood danger. The Southern Railway follows the edge of the overflow area and is subject to damage by large floods.

Estimated Flood Damages Caused by Repetition of Past Floods
(Development in Basin Same as in 1941)

Flood	Gage Height at Blantyre	Total Flood Damage
February 1875	17.0	$ 15,900
June 1876	23.0	207,600
October 17, 1879	19.0	53,400
September 13, 1893	18.0	33,100
March 15, 1899	17.0	15,900
March 19, 1899	17.0	15,900
May 22, 1901	20.0	78,800
February 28, 1902	19.0	53,400
July 1905	21.0	107,900
January 23, 1906	22.0	157,900
August 31, 1910	21.0	107,900
May 23, 1916	17.0	15,900
July 10, 1916	22.0	157,900
July 16, 1916	27.2	531,900
October 25, 1918	17.0	15,900
October 29, 1918	20.0	78,800
August 16, 1928	22.90	207,600
March 14, 1929	19.20	53,400
October 17, 1932	20.68	107,900
March 5, 1934	17.32	15,900
January 10, 1935	18.29	33,100
April 7, 1936	18.85	53,400
October 17, 1936	17.43	15,900
January 7, 1937	17.70	33,100
October 20, 1937	18.83	53,400
August 19, 1939	17.40	15,900
August 13, 1940	21.88	157,900
August 31, 1940	19.31	53,400
Total -		$ 2,449,000

Classified Damages--Agricultural damage amounts to 88.2 percent of the total loss. The loss suffered by railroads and highways amounts to $202,200, or 8.2 percent of the total. Smaller losses are distributed as shown.

Type of Damage	Amount	Percent
Industrial	$ 12,500	0.5
Commercial	6,800	0.3
Domestic	6,800	0.3
Highways	83,600	3.4
Railroads	118,600	4.8
Utilities	61,400	2.5
Agricultural	2,159,300	88.2
Total - - - - - - - -	$ 2,449,000	

Swannanoa River Basin

In the valley of the Swannanoa River is a concentration of industrial plants, commercial establishments, utilities, and residential areas all subject to periodic devastating floods which through the years have resulted in loss of life and caused great destruction of property.

In addition to the direct damage there is an indirect damage resulting from the devaluation of land and property located principally in the Biltmore industrial area. This damage to land and property value is estimated by an appraisal board composed of ten competent members of the Asheville Real Estate Board to amount to $634,000. The determination of this amount is explained in a succeeding section of this Appendix.

Estimated Flood Damages Caused by Repetition of Past Floods
(Development in Basin Same as in 1941)

Flood	Gage Height at Biltmore	Total Flood Damage	Damage Below Proposed Dam Site	Damage Above Proposed Dam Site
April 1791	26	$ 1,500,000	$ 1,150,000	$ 350,000
August 1796	15	52,000	45,000	7,000
1810	15	52,000	45,000	7,000
May 1845	18	206,000	141,000	65,000
August 1850	13	14,000	11,200	2,800
August 1852	15	52,000	45,000	7,000
February 1875	17	130,000	100,000	30,000
June 17, 1876	15	52,000	45,000	7,000
March 19, 1899	14	18,000	15,000	3,000
May 21, 1901	16	88,000	77,000	11,000
December 30, 1901	15	52,000	45,000	7,000
February 28, 1902	14	18,000	15,000	3,000
July 10, 1916	14	18,000	15,000	3,000
July 16, 1916	20.7	1,230,000	941,000	289,000
August 16, 1928	18.7	206,000	141,000	65,000
August 13, 1940	18.95	290,000	185,000	105,000
August 30, 1940	15.30	28,000	19,000	9,000
Land and Property Devaluation		634,000	634,000	--
Totals - - - - - - - - - - - - - - -		$ 4,640,000	$ 3,669,200	$ 970,800

Classified Damages--Damages to industries located in the flood plain amount to 46.4 percent of the total. Damage to transportation systems including both highways and railroads amounts to 29 percent of the total with the remainder distributed as shown.

Type of Damage	Amount	Percent
Industrial	$ 2,152,300	46.4
Commercial	149,500	3.2
Domestic	69,200	1.5
Municipal	132,300	2.9
Highways	417,900	9.0
Railroads	930,700	20.0
Utilities	8,500	0.2
Agricultural	145,600	3.1
Land & Property Devaluation	634,000	13.7
Total - - - - - - - -	$ 4,640,000	

Asheville Water Front

Industries, warehouses, and numerous commercial firms are located in the flat area along the French Broad. This improved area, extending from the mouth of the Swannanoa River down to Beaverdam Creek, is subject to inundation from floods which have resulted in loss of life and an ever-increasing damage to property.

Flood damage consists of the actual physical loss, lost business, and loss of payroll. In carrying out the investigation of flood damage in this area it became apparent that another type of damage had resulted from, and should be charged directly to, the recurring floods. This damage is the devaluation of property in the flood area. A committee composed of ten members of the Asheville Real Estate Board reported land and property values had depreciated $784,000 as a result of the flood hazard. The determination of this amount is explained in a succeeding section of this Appendix.

Estimated Flood Damages Caused by Repetition of Past Floods
(Development in Basin Same as in 1941)

Flood	Gage Height	Total Flood Damage	Flood	Gage Height	Total Flood Damage
April 1791	-	$ 2,400,000	May 22, 1901	11	$ 41,000
August 1796	14	255,000	Dec. 29, 1901	9.4	13,000
1810	13	81,000	Feb. 28, 1902	11.6	50,000
May 1845	14	255,000	Jan. 23, 1906	8.9	13,000
August 1850	13	81,000	Aug. 31, 1910	11.6	41,000
August 1852	15	370,000	July 11, 1916	10.7	23,000
February 1875	9	13,000	July 16, 1916	23.1	2,108,000
June 1876	18	1,035,000	Oct. 30, 1918	9	13,000
October 1879	9	13,000	Dec. 23, 1918	10	23,000
June 1892	10	23,000	Aug. 16, 1928	13.3	81,000
Sept. 23, 1893	9	13,000	Aug. 13, 1940	11.7	41,000
March 15, 1899	10	23,000	Aug. 30, 1940	12.1	50,000
March 19, 1899	9.8	23,000	Land & Property Devaluation		784,000
Total -					$ 7,866,000

Classified Damages--With excellent transportation facilities available, numerous industrial plants have located in this area. All are subject to damage from the recurring floods and through the years have suffered a tremendous loss. Should a repetition of these floods occur 73.1 percent of the total loss would be industrial. Damage to railroad property, commercial establishments, and other types of damage resulting from a repetition of these floods bring the total for the period 1791 to 1940 to $7,866,000, representing approximately 40 percent of the total loss during this same period for the entire basin. Coupled with the loss of $4,640,000 in the Swannanoa River Basin, the major part of which occurs in the Biltmore section of Asheville, the total loss at Asheville alone amounts to $12,506,000, or 63 percent of the total loss for the entire basin under present conditions of development.

Type of Damage	Amount	Percent
Industrial	$ 5,750,600	73.1
Commercial	166,700	2.1
Domestic	8,800	0.1
Municipal	109,800	1.4
Highways	73,700	0.9
Railroads	873,600	11.1
Utilities	90,300	1.2
Agricultural	8,500	0.1
Land and Property Devaluation	784,000	10.0
Total - - - - - -	$ 7,866,000	

Lower French Broad Basin

Flood waters of the French Broad River from Asheville downstream to the mouth of the Pigeon River flow through a comparatively narrow valley. Marshall and Hot Springs, North Carolina, are the only towns of any size located in the flood plain. Near the mouth of the Pigeon River the valley opens out and a considerable area of farm land is subject to overflow. Highways are subject to flooding at several points. The Southern Railway which follows the river downstream from Asheville is severely damaged by large floods.

Estimated Flood Damages Caused by Repetition of Past Floods
(Development in Basin Same as in 1941)

Flood	Gage Height at Marshall	Total Flood Damage	Damage Above Marshall	Damage At Marshall	Damage Below Marshall
August 1796	17.0	$ 64,600	$ 13,450	$ 17,270	$ 33,880
1810	15.0	24,300	5,600	5,600	13,100
May 1845	17.0	64,600	13,450	17,270	33,880
August 1850	16.0	42,600	9,500	10,300	22,800
August 1852	18.0	106,100	22,560	32,600	50,940
June 1876	21.0	246,500	40,100	90,950	115,450
May 1901	13.0	8,000	900	2,000	5,100
December 1901	13.0	8,000	900	2,000	5,100
February 1902	21.0	246,500	40,100	90,950	115,450
August 1910	14.0	12,900	1,375	3,000	8,525
July 11, 1916	13.0	8,000	900	2,000	5,100
July 16, 1916	24.0	725,200	142,950	234,300	347,950
August 1928	16.3	42,600	9,500	10,300	22,800
August 14, 1940	14.5	12,900	1,375	3,000	8,525
August 30, 1940	20.3	214,400	36,090	93,060	85,250
Total		$ 1,827,200	$ 338,750	$ 614,600	$ 873,850

Classified Damages--Railroad property in this reach of the river would suffer the greatest damage as a result of a repetition of past floods. Damage to commercial establishments would be high due to the condition at Marshall, North Carolina. These losses are shown in the accompanying table.

Type of Damage	Amount	Percent
Industrial	$ 132,700	7.3
Commercial	243,850	13.3
Domestic	39,500	2.2
Municipal	34,500	1.9
Highways	234,000	12.8
Railroads	813,100	44.5
Utilities	13,850	0.7
Agricultural	315,700	17.3
Total - - - - - - -	$ 1,827,200	

Pigeon River Basin

Flood damage in the Pigeon River watershed is mostly confined to the Upper Pigeon River in the vicinity of Canton. Canton is the site of the Champion Paper and Fibre Company which is subject to overflow by large floods. Parts of the business and low-cost residential districts are subject to overflow by major floods. Crops on farms in the bottoms are damaged by flooding. The steep slopes of the streams result in swift currents that cause considerable damage to land.

Estimated Flood Damages Caused by Repetition of Past Floods
(Development in Basin Same as in 1941)

Flood	Gage Height At Newport	Gage Height At Canton	Total Flood Damage
1810	18.0	20.0	$ 459,500
March 1867	21.5	-	62,400
June 1876	21.0	18.3	229,000
1885	16.0	-	20,650
September 1893	15.0	17.8	192,650
May 1901	-	13.0	4,200
December 1901	-	11.0	400
February 1902	21.3	12.0	66,800
August 1910	-	12.5	2,900
March 1917	14.4	-	13,250
October 1918	-	13.0	4,200
April 1920	17.0	-	46,800
August 16, 1928	12.4	16.4	29,850
January 1936	13.9	-	11,400
March 1936	12.6	-	5,250
April 1936	13.7	-	11,400
August 13, 1940	16.0	18.0	193,450
August 30, 1940	17.3	20.9	484,900
Total			$ 1,839,000

Classified Damages--Due to the flooding of the industrial section of Canton the industrial damage exceeds all other types. The flooding of the fertile intensively cultivated valleys with damage not only to the crops but to the land as well results in a high agricultural loss.

Type of Damage	Amount	Percent
Industrial	$ 830,050	45.2
Commercial	33,300	1.8
Domestic	50,150	2.7
Municipal	21,550	1.2
Highways	237,350	12.9
Railroads	6,400	0.3
Utilities	1,400	0.1
Agricultural	658,800	35.8
Total - - - - - - - -	$ 1,839,000	

Devaluation of Property in Biltmore Section and on Asheville Water Front Due to Prevailing Flood Hazard

The estimated damages resulting from each flood of record represent actual physical losses, lost business, and loss of payroll as the result of and directly attributable to, each particular flood. In making the damage surveys, it became evident that another type of damage had resulted from and should be charged directly to the recurring floods in the

Swannanoa Basin and on the French Broad at Asheville. This damage is the devaluation of property in the flood area, especially the property in the extensively developed area in the Biltmore section and in the industrialized area along the right bank of the French Broad through Asheville.

This type of damage is difficult to evaluate. Land values in the area are based on the accessibility of transportation facilities and the adaptability principally to industrial or commercial uses. If the flood hazard is removed, land in these areas should have a high value since these are the only flat areas around Asheville adaptable to industrial and commercial development which have transportation facilities. Under present conditions, the areas are servient to floods, and heavy losses from successive floods have had a definite depreciating effect on land values.

Immediately following each of the past floods, land values have depreciated. As the years passed after each flood, the memory of the flood and the damage it did was dimmed, new plants moved in, and land values rose again. However, many of the industries and commercial firms now in this area have suffered major losses from not one but several floods. These firms definitely fear the recurrence of another major flood and have either made plans to leave the area or have curtailed plans for expansion. The devaluation is not chargeable to one particular flood but is attributable to the depressing effect of the existing flood hazard.

This condition was discussed with Mr. R. Fred Gray, Chairman of the Asheville Flood Control Committee, and the following procedure was adopted to determine the devaluation of this property.

1. A committee, composed of ten competent members of the Asheville Real Estate Board, was appointed. This committee was directly responsible for all appraisal work in connection with this investigation.

2. The Tax Supervisor prepared an actual inventory of property in the area using 1940 valuation for tax purposes, these figures representing the valuation just prior to the 1940 floods. This valuation was based on assessment of property for tax purposes taken by Board of Tax Supervision as the actual value of property representing a normal selling price.

3. The Appraisal Committee made an appraisal of depreciated values resulting from floods.

4. The Committee's appraisal was applied to full valuation of property just prior to 1940 floods.

5. The Committee appraised and reported on effect of flood protection on value of property in area.

Biltmore Section of Asheville--The Tax Supervisor's inventory of assessed valuation of property in the area totaled $975,000. The Appraisal Committee's report, Exhibit 1, estimated depreciation due to floods of 65

percent of property values. Applying this devaluation gives the following results:

Classified Land Use	Full Value Prior to 1940 Flood	Present Depreciated Value	Depreciation Resulting From Floods
Industrial (75 percent)	$ 731,750	$ 256,100	$ 475,650
Domestic (15 percent)	146,350	51,200	95,150
Agricultural (10 percent)	97,600	34,200	63,400
Total	$ 975,700	$ 341,500	$ 634,200

With regard to recovery in values, if the flood hazard were eliminated, the Committee reported, Exhibit 2, ". . . the properties would immediately regain something like 40 percent of this 65 percent depreciation and over a period of three to five years regain their 1940 values."

Asheville Water Front--Translating the Appraisal Committee's conclusions into a monetary value gives the following results:

Tax Supervisor's inventory of assessed valuation of property in the area which represents the full valuation of this land prior to the 1940 floods - - -	$ 1,425,700
Committee's appraisal of the present depreciated value of the land in this area - - - - - - - - - - - -	641,700
Devaluation in land value resulting from floods - - -	784,000

It is stated in the Appraisal Committee's report "We believe that if further floods of this area could be prevented by control projects that the real estate value would increase substantially and rapidly."

Agricultural Damages

In determining flood damages to agricultural lands, the work was carried out in close cooperation with the County Agents. In addition to actual losses, the possibilities of the agricultural lands if protected from floods were explored.

The agricultural situation with respect to floods and flood protection and the benefits that may be realized from such protection are discussed in letters from County Agent D. W. Bennett of Henderson County, County Agent J. A. Glazener of Transylvania County, County Agent J. C. Lynn and Assistant County Agent J. L. Reitzel of Haywood County. Copies of these letters follow as Exhibits 3 to 6.

MEMBERS OF

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NORTH CAROLINA ASSOCIATION OF REAL ESTATE BOARDS

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ASHEVILLE, N. C.

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MRS. LENORE A. GASKINS
EXECUTIVE SECRETARY

March 25, 1941

Mr. Sherman M. Woodward, Chief Water Control Planning Engineer
Tennessee Valley Authority,
Knoxville, Tennessee

Dear Sir:

Re: Property in the Swannanoa Valley Flood Area

We, the undersigned, are familiar with property values in the flood area of the Swannanoa River Valley and have been requested to express our opinion as to the devaluation of property in said flood area caused by the 1928 and 1940 floods.

It is our opinion that these two serious floods have depreciated the market value of most of the property which was under water to the extent of 65% of its value. We believe that if further floods of this area could be prevented by Control Projects that the real estate values would increase substantially and rapidly.

Yours very truly,

R. P. Booth & Company
R. P. Booth

Weaver & Coleman

York & Company
Arthur A. York

Powers & Company
Hayward Perry

Huntington-Johnson Co.
H. E. Johnson

Gray Realty Company
R. Fred Gray

B. H. Sumner & Son
W. B. Sumner

Gray-Gorham Company
Geo. G. Gorham

Carroll Realty Company

Tom Rowland, Jr.
Tom Rowland Jr.

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FIRST VICE PRESIDENT

D. J. WEAVER
SECOND VICE PRESIDENT

MRS. LENORE A. GASKINS
EXECUTIVE SECRETARY

April 4, 1941

Mr. Van Court Hare,
Tennessee Valley Authority,
703 Union Building,
Knoxville, Tennessee

Dear Mr. Hare:

Relative to increases in value if future floods were eliminated, it is our opinion that if flood preventive measures were taken in this Swannanoa River Basin Area that were acceptable to the public, we feel that the 65% depreciation which we show on todays tax valuation would increase rapidly. We mean by that that the properties would immediately regain something like 40% of this 65% depreciation and over a period of three to five years regain their 1940 values.

Hoping you will be able to fit this information into your report in a satisfactory manner but if there is anything further that we can secure which would expedite your report, please do not hesitate to call upon us, we are

Yours very truly,

R. P. Booth & Company

Arthur A. York

York & Company

Gray Realty Company

COOPERATIVE EXTENSION WORK
IN
AGRICULTURE AND HOME ECONOMICS
STATE OF NORTH CAROLINA

NORTH CAROLINA STATE COLLEGE OF AGRICULTURE AND ENGINEERING
NORTH CAROLINA COUNTIES AND UNITED STATES DEPARTMENT OF AGRICULTURE COOPERATING

EXTENSION SERVICE
COUNTY AGENT WORK

Hendersonville, N. C.
May 21, 1941

Mr. Van Court Hare, Civil Engineer
Tennessee Valley Authority
Knoxville, Tennessee

Dear Mr. Hare:

The Mills River Valley is a noted truck growing area but the main crops at the time of the 1940 August flood were corn, soybeans, and crimson clover. Only between 175-200 acres of green beans were in the flooded area during 1940 with about 50 acres of cabbage, tomatoes, potatoes and other high valued crops.

One large farm has in the past grown seeds for sale, chiefly soybeans and snapbeans, but last year there was not to my knowledge only about 25 acres in the Mills River Valley planted to crops for seed purposes.

We have checked the yield figure for each farmer obtained by Mr. Ristau during his survey and state that they represent an average yield applicable to each farm in the overflow area.

Many of the bean fields have yields of from 100-200 bushels per acre which at the price prevailing during the 1940 floods represent a loss per flooded acre of $150.00 to $300.00 per acre.

Sincerely yours,

D. W. Bennett
D. W. Bennett
Ass't County Agent

COOPERATIVE EXTENSION WORK
IN
AGRICULTURE AND HOME ECONOMICS
STATE OF NORTH CAROLINA

NORTH CAROLINA STATE COLLEGE OF AGRICULTURE AND ENGINEERING NORTH CAROLINA COUNTIES AND UNITED STATES DEPARTMENT OF AGRICULTURE COOPERATING

EXTENSION SERVICE
COUNTY AGENT WORK

May 26, 1941

Mr. VanCourt Hare
Hydraulic Engineer
Tennessee Valley Authority
Knoxville, Tennessee

Dear Mr. Hare:

As stated to you in my office Saturday, this county at the present time is not a commercial seed producing section, other than soy beans on a small scale. Flood damage discouraged the expansion of that idea. Commercial truck farming is not extensively done at the present time, but offers a wonderful possibility, provided there could be flood control in the area. As explained to you, industry is expanding rapidly in our county which in turn is increasing our population. This would offer the farmers a good opportunity for commercial, fruit and vegetable farming.

Yours very truly,

J. A. Glazener

J. A. Glazener,
County Agent

JAG:MS

COOPERATIVE EXTENSION WORK
IN
AGRICULTURE AND HOME ECONOMICS
STATE OF NORTH CAROLINA

NORTH CAROLINA STATE COLLEGE OF AGRICULTURE AND ENGINEERING
NORTH CAROLINA COUNTIES AND
UNITED STATES DEPARTMENT OF AGRICULTURE COOPERATING

EXTENSION SERVICE
COUNTY AGENT WORK

Waynesville, N. C.
July 1, 1941.

Mr. Van Court M. Hare
Tennessee Valley Authority
Knoxville, Tennessee

Dear Mr. Hare:

With reference to the detailed survey just completed of the Pigeon River to determine the damage and extent of the flood, I would like to submit some information as to the effect of the flood on the agricultural life in that section.

The value of the land on Pigeon River is high due to the density of population and the high yield of crops prevailing in the area. A large percentage of the people living on Pigeon River is dependent upon the soil for a livelihood. In recent years some of the land has been sold at prices ranging from $400.00 to $800.00 per acre.

The yields per acre in this area are above normal yields for Haywood County due to the fertility of the soil and the intensive cultivation methods. For two years the adult corn contest held by farmers of Haywood County has been won by a farmer on Pigeon, his yield being 116 and 123 bushels per acre. On farms of similar size and fertility, yields of 250 bushels of snapbeans are very common. This will substantiate the high land damage per acre given by farmers and shown in the detail report. The prices established in the French Broad and Mills River areas are comparable to the ones that prevail in this area.

The channel of the river has been greatly damaged by the floods of last summer. Due to this damage, one farmer was interviewed who had moved from a very fertile 40-acre farm to higher ground because of the fear of another overflow and due to the eating away of his land. Other farmers in this particular area (Love Joy area) have expressed the desire to sell their farms and move to other places, due to the hazardous condition prevailing. As may be substantiated by a map that has been prepared by the Champion Paper & Fibre Company, many shoals have accumulated in Pigeon River, filling the channel to a depth of from 2½ to 5 feet of rock and gravel. With the present condition of the channel, a flood of 1/2 the size of the first flood of last summer would run over about as many crop acres due to these rock beds and shoals. My opinion, and the opinion of the farmers of this area, is that if these shoals could be removed, it would greatly increase the carrying capacity of the river bed.

Lime and phosphate are being used very effectively on the slopes of the Pigeon River Watershed to establish better sods of grasses and legumes, which will greatly effect the amount of silt going into the stream channel. However, unless the stream channel can be improved, the benefits of these materials would be lessened due to the lowlands being flooded.

We appreciate the cooperation being given by the Tennessee Valley Authority in helping to control soil erosion and floods; and if effective measures can be taken to control the floods, we believe that the standard of living of the people in Pigeon Valley will be raised. If adequate flood control measures are taken, it will cause a shifting of the cropping system back to more cash crops on the bottom land such as truck crops and tobacco.

Very truly yours,

J C Lynn

J. C. Lynn,
County Agent

JCL:mm

EXHIBIT 6

PIGEON RIVER BASIN - HAYWOOD COUNTY

DAMAGE RESULTING FROM THE FLOODS OF AUGUST, 1940

With the cooperation of the Hydraulic Data Division of the Tennessee Valley Authority, a detail survey was made in the Pigeon River basin to determine the agricultural damage which was caused by the floods of August, 1940. In making this survey, all the farmers who were damaged by the flood have been contacted and they have aided greatly in giving us an accurate account of all the agricultural damages caused by the flood. I accompanied representatives of the Hydraulic Data Division in making these contacts, and in all cases tried to keep the damages and the yields consistent. At the request of Mr. Van Court M. Hare, there were certain items which he thought necessary to be brought out in my report to aid in clarification.

The Champion Paper and Fibre Company, which is located at Canton, N. C., has been in operation for a period of over twenty-five years, and during this period it has encouraged its employees to own and live on a small farm within this area. For the past several years the officials of this company have done what they could to encourage a sound agriculture program in the section; however, it has been within the past four years that they have found a medium through which they may lend direct aid to the agriculture of this section. At the present time they are working hand-in-hand with the Extension Service and the Agricultural Relations Division of the Tennessee Valley Authority to promote an agriculture program which will improve the soil, maintain or increase the present income, and at the same time set up a farm program which will prevent soil erosion and water run-off.

Crop Yields

The crop yields which are found in the Pigeon River basin based on corn yields will be on the average around 55 bushels per acre. I have records of many farms in this section for the past two years which will substantiate this 55-bushel yield. The yields of other crops are in proportion to corn yields. These high yields may be attributed to a good Congaree silt loam soil and fair management for the past years. The land along the Pigeon River is particularly adapted to the production of tobacco and truck crops, and these yields will run much above the county average. As previously stated, I aided in making the recent survey and have checked the yields on all the flood survey forms and I am certain that they are not above average production.

Value of Agricultural Land

The prices of agricultural land in this section are very high, and this is particularly true of the bottom land of the Pigeon River basin. As previously stated, the Champion Paper & Fibre Company has been in operation for a period of over twenty-five years and during this time it has encouraged

its employees to own and live on a small farm. This company has furnished a rather stable income, and its employees have prospered along with the company.

The land along the Pigeon River is the best type of Congaree loam and is very adapted to the production of truck crops, tobacco, corn, and hay crops. This land has been well managed, and at the present time is in a very high state of cultivation. It is not uncommon for farmers of this area to obtain a corn yield of from 75 to 100 bushels per acre. The productivity of this land can substantiate a very high value per acre.

Another reason which should not be overlooked for the high valuation on this land is the fact that many farmers in this section have a large number of acres of steep grassland and depend upon the flat land to produce their feed for cattle during the winter months. In our survey we found that no one farmer owned a very large area of the bottom land.

Another factor to be considered is the scarcity of the bottom land in this section. Practically every acre of bottom land available which is suitable for cultivation is being utilized. It is very difficult to acquire any of this land, regardless of the price. In making our recent survey on flood damages, we made it a point to inquire as to the prices of this land. We found a range from $200 to $800 per acre. We found no land that could be bought at the $200 figure. In arriving at a figure to determine the value of the land which was damaged by the flood, we have taken all the above figures into consideration and placed this damage at $300 per acre.

Land Damage

In clarifying the land damage on this flood survey, for land to appear to show 100% damage, it must be completely ruined from an agricultural standpoint. By this we mean that the top soil has been completely washed away down to the parent material, or gravel, to a depth that no top soil can be plowed up or has been sanded with coarse, white sand to such a depth as to make it impossible to produce crops. Land appearing in the above condition has been shown in our survey as damaged 100 percent. From the 100 percent damage we consider the land that has been partially damaged, either by the washing away of top soil or the deposits of sand, owing to the extent of each. We have shown land that was damaged to the extent of 75%, 60%, 50%, 40%, and 25%.

Arriving at a total acreage of land damaged, I have calculated the 100 percent damage as a total loss and the other damages by the percent damaged as shown up in our flood survey reports. An example: 90 acres of land with 50% damaged would equal 45 acres of total land damage. The total acreage of land damaged by the flood as shown by the survey is 193.4 acres. Based on the above acreage, the total land damage of the Pigeon River basin will be valued at $58,020.00. This damaged acreage is figured at $300 per acre. Even though this land damage figure is rather high, I feel that this does not cover the total damage, since the flood threw up many shoals in the river which makes all the bottom land within the basin more vulnerable to floods. These shoals have made it necessary for the farmers to decrease their truck crop acreage and their tobacco crop acreage and to use this

bottom land for crops which are less likely to be damaged by future floods or future high waters. This shifting of the land management of this section will decrease materially the income in the future unless some permanent flood control measures can be brought about. In case these measures are brought about, the bottom land of the Pigeon River basin would be used for the production of more truck and cash crops.

Summary

When the flood survey sheets have been summarized, we will have placed an economic value on the flood of August 1940; however, the actual damage will not show up on this report since much of the land which is much more susceptible to future floods could not be taken into consideration. The loss of the past flood has already had its effect upon the cropping system that will be carried out on these lands in the future, unless some permanent flood control measures can be brought about. If some permanent flood control measures could be brought about, the income of the people in this section would be increased above the pre-flood period level. This increase would be brought about by the additional acreage of truck and cash crops. The present condition of the stream would make it unwise to use this bottom land for intensified farming. For the past four years we have been making every effort in this section to encourage the farmers to bring the plow from the hill, and feel that much progress has been made along this line; however, unless this bottom land can be made safer for crop production, in many cases it will be necessary for the farmers to plow the sod on the hill to earn a livelihood.

I appreciate the interest that the Tennessee Valley Authority has taken in this area, and I am ever willing to lend my aid whenever possible.

(Signed) J. L. Reitzel
Assistant County Agent

Waynesville, N. C.
July 1, 1941

Tennessee Valley Authority
Water Control Planning Department
Hydraulic Data Division

APPENDIX C

RAINFALL

IN

FRENCH BROAD REGION

Knoxville, Tennessee
August 1942

CONTENTS

APPENDIX C

RAINFALL IN FRENCH BROAD REGION

I. AVERAGE ANNUAL RAINFALL

The average annual rainfall in the French Broad River Basin above Asheville, North Carolina, is about 57 inches. This is five inches more than the average for the whole Tennessee River Basin. In general, the average annual amounts increase in an upstream direction from about 40 inches at Asheville to over 70 inches at Rosman, North Carolina, near the headwaters of the river. Table 1 shows annual precipitation in this region as measured at 21 stations. The maximum and minimum annual precipitation are also shown. At two stations near the upper end of the basin, over 100 inches of rain have been recorded in one year's time. Plate 43 is an isohyetal map of mean annual rainfall.

The eastern half of the French Broad River Basin above Asheville, or that portion lying between the Atlantic divide and the river, is gently sloping since the divide along the eastern rim is relatively low for this mountainous section. The eastern rim of the basin averages only about 1000 feet higher than the valley. However, this rim is between 3000 and 4000 feet above sea level and is the first high ground west of the Atlantic sea coast. Consequently, storm clouds moving westward from the coast are lifted or forced upward along the gradual Atlantic slope with the result that the basin divide and the eastern half of the French Broad Basin are subject to the heavy rainfall resulting from this orographic effect. The annual rainfall is about ten inches greater near the eastern divide than in the valley.

The western half of the basin or that portion lying between Pisgah Ridge and the river, is fairly flat near the river, but increases in slope quite sharply a few miles west of the French Broad River and rises up to elevations over 6000 feet above sea level. This abrupt slope exerts a further lifting on storms moving westward and so the western portion of the basin is also subject to heavy, intense rains, particularly from storms of the tropical hurricane and summer thunderstorm types. These types of storms are the ones that have produced the great floods of the past in this region. Average annual rainfall along the western divide exceeds that in the valley from five to ten inches.

II. GREAT STORMS OF THE PAST

To determine the flood characteristics and a reasonable procedure for developing a hypothetical design storm, study has been given to the great storms of the past which have occurred in the upper French Broad area.

The greatest floods of record and the majority of all floods have occurred in the summer. For detailed study, analyses were made of the flood of July 1916, which is the greatest of record, and the floods of August 1940, which are the only floods for which reasonably complete meteorological and hydrological data is available.

TABLE 1

ANNUAL PRECIPITATION IN THE FRENCH BROAD RIVER BASIN

ABOVE ASHEVILLE, NORTH CAROLINA

Station	Elevation Feet	Period of Record Years	Annual Precipitation Mean Inches	Max. Inches	Year	Min. Inches	Year
Asheville, N. C.	2192	62	40.28*	52.86	1875	22.79	1925
Beetree Gap, N.C.	4900	7	49.80	69.82	1936	38.15	1941
Beetree Dam, N.C.	2557	17	48.36	61.16	1929	30.94	1925
North Fork, N. C.	2950	16	57.72	85.50	1929	38.96	1930
Swannanoa, N. C.	2250	10	43.26	55.76	1936	32.30	1941
Montreat, N. C.	2600	24	56.10*	67.77	1929	35.49	1925
Enka, N. C.	2075	10	36.06	49.36	1936	28.81	1941
Bent Creek, N. C.	2100	8	41.65	58.08	1936	34.49	1941
Garren Creek, N.C.	2600	6	56.56	75.69	1936	38.61	1941
A&H Airport, N. C.	2080	7	45.29	60.04	1936	36.21	1941
Blue Ridge P.O.,N.C.	2270	7	55.19	78.78	1936	42.57	1941
Rush Mountain, N.C.	2900	7	68.80	92.68	1936	52.46	1938
Hendersonville,N.C.	2153	44	59.42*	92.60	1901	32.55	1925
Mt. Pisgah, N. C.	5300	7	59.01[b]	76.81	1940	46.89	1938
Pink Beds, N. C.	3300	5	69.83	79.74	1937	51.58	1941
Horseshoe, N. C.	2150	7	54.95	68.55	1936	45.06	1941
Cedar Mountain,N.C.	2750	6	73.97	88.69	1936	56.68	1941
Caesar's Head, N.C.	3115	17	71.94*[c]	101.56	1932	46.17	1925
Brevard, N. C.	2250	39	62.00*	101.42	1906	30.65	1925
Rosman, N. C.	2250	7	73.19	89.12	1936	56.86	1941
Owen's Gap, N. C.	4100	7	72.05[a]	82.16	1936	65.14	1938

*USWB normals, all others are arithmetical means.
[a]In Little Tennessee River drainage but near French Broad watershed.
[b]In Pigeon River drainage but near French Broad watershed.
[c]Outside basin, but near French Broad watershed.

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

UPPER FRENCH BROAD AREA
SHOWING
AVERAGE ANNUAL RAINFALL

Storm of Mid-August, 1940

Meteorological Aspects of the Storm -- The storm of mid-August 1940 was of tropical origin, having developed in the Atlantic Ocean east of the Bahamas sometime prior to August 8, 1940, when it first became noticeable on the weather map. It was of hurricane intensity when it moved inland over Georgia and South Carolina. The path of the storm is unusual for a West-Indian hurricane, in that it moved inland a considerable distance and then recurved, describing the greater portion of a circle as its center passed approximately over Savannah, Atlanta, Chattanooga, Bristol, and Greensboro, North Carolina.

Since tropical storms usually drift in the direction of prevailing winds, the reason for this unusual trajectory is found in an analysis of upper air wind directions. In this case winds were predominantly east and east-southeast as far inland as Atlanta, due to a considerable westward displacement of the permanent Atlantic anticyclone. This resulted in a west-northwesterly movement of the storm as far as Atlanta. At this point the more southerly winds caused it to recurve and move in a northerly direction toward Chattanooga and Bristol. The final portion of the arc from Bristol to Greensboro was caused by the prevailing easterly winds still present near the coast.

The storm probably reached its maximum intensity with winds in excess of 75 miles per hour during August 11, when it moved inland near Savannah. Normally, this type of storm dissipates rapidly when moving inland due to the absence of sufficient moisture and the increased surface friction over land. In this case, the storm decreased in intensity near the surface, but maintained its intensity and high moisture content at higher levels.

Storm Rainfall, General -- The rainfall which accompanied the mid-August storm over the southeastern United States is shown on the isohyetal map, plate 2, of the report "Floods of August, 1940 in Tennessee River Basin." The path of the rainfall parallels roughly the path of the storm center and forms approximately a large letter U with the base along the Blue Ridge Mountains of western North Carolina, one arm extending to Savannah, Georgia, and the other from the Virginia state line to the North Carolina coast line.

Centers of high rainfall reached 14 to 16 inches along the Blue Ridge Mountains in western North Carolina, 13 inches in Georgia and South Carolina, 15 inches in southern Virginia, and 18 inches on the coast of North Carolina. Central North Carolina received only 4 to 6 inches of rain although completely encircled by areas of much heavier rainfall.

Storm Rainfall, Upper French Broad Basin -- The isohyetal map for the mid-August storm, plate 44, clearly indicates the close association between rainfall and topography. This shows that the upper French Broad region is bounded along its rim by about 12 inches of rain to the south and west and about 10 inches on the east. An area of low rainfall extends up

the valley of the French Broad from the north with amounts less than 5 inches along the river above Asheville.

Rainfall occurred principally during a 48-hour period from August 11 to 13 while the storm center traveled in an arc from southeastern Georgia to northeastern Tennessee. During this time the counterclockwise air movement about the center was approximately normal to the southern Appalachians, which is the most effective direction to produce lifting of the air. The vertical motion produced by the physiographic features caused precipitation increments in excess of those produced by the storm alone. Rainfall intensities in this storm, although heavy, were not excessive, being generally less than one inch per hour.

Analysis of Rainfall and Run-off -- Rainfall records from the regularly established daily and recording stations were supplemented by additional catches located immediately following the storm. Streamflow records were obtained on the French Broad and its principal tributaries. Taken together, the rainfall and run-off records are valuable basic data for evaluating the flood characteristics of that area.

The rainfall and run-off records of this flood have been analyzed to determine the infiltration rates for each major tributary area. Infiltration rate has been defined as "the maximum rate at which a terrain can absorb falling rain when in a given condition." The infiltration rates determined were later invaluable in determining the rainfall of the July 1916 and the hypothetical design storm.

Storm of Late August 1940

Meteorological Aspects of the Storm -- The storm of late August occurred during about a 24-hour period on August 29 and 30, 1940. Unlike the storm of mid-August, it did not originate as a well-defined storm center and it produced heavy rains only along the Southern Appalachian Mountains of eastern Tennessee and western North Carolina.

The storm occurred after a broad and relatively deep current of moist, tropical air had been flowing over this region for a number of days, producing scattered showers and thunderstorms. During the night of August 29-30, a mass of cool polar air moved southward along the Atlantic coast. This resulted in a general steepening of the isentropic surfaces over this region, with the greatest slope in a northeast-southwest axis. A strong southerly current carried tropical air up these rather steep isentropic surfaces. This resulted in releasing the available energy of the unstable tropical current of air, which in turn produced heavy shower activity. The physiographic features of the area undoubtedly aided in initiating the release of shower activity.

Storm Rainfall, General -- The rainfall in the late August storm over the southern Appalachian region is shown on the isohyetal map, plate 14, of the report "Flood of August 1940 in Tennessee River Basin." Rainfall amounts up to 13 inches occurred in a relatively narrow band along the

~10~ INCHES RAINFALL

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

UPPER FRENCH BROAD AREA
SHOWING
MID-AUGUST 1940 STORM RAINFALL

Blue Ridge Mountains in western North Carolina. Total rainfall decreased rapidly in all directions from this mountain ridge, so that at about 50 miles distant only about 2 inches was recorded.

Storm Rainfall, Upper French Broad Basin--The isohyetal map for the late August storm, plate 45, indicates the same general rainfall topography relation as found in the mid-August storm. Low rainfall occurred near Asheville and in the river valley farther upstream to the vicinity of Blantyre. Along the rim of the basin to the southeast and northwest, higher rainfall of about 8 inches coincided with the major mountain ridges.

Rainfall intensities at those stations receiving heavy rainfall were generally higher than in the mid-August storm. Maximum intensities ranged between 1 and 2 inches per hour except at Mount Pisgah where they exceeded 2 inches.

Analysis of Rainfall and Run-off--Rainfall and run-off records similar to those described for the mid-August storm were collected. These data were analyzed to determine infiltration rates. The infiltration rates for this storm were generally higher than for the mid-August flood since the main portion of the storm was not immediately preceded by rain which would lower the rate. In addition, the rainfall duration was too short to lower the rate to a minimum as in the earlier storm.

Storm of July 1916

Meteorology of the Storm--Like the storm of mid-August 1940, the storm of July 1916 originated as a tropical hurricane. It passed inland over Charleston, South Carolina, on July 14 with winds of near hurricane intensity. The storm center advanced northwestward across South Carolina and finally was dissipated over the upper French Broad Valley on July 16.

This tropical storm was prevented from following the more usual track along the Atlantic coast by a high-pressure area centered over the northeastern states. As the storm advanced over South Carolina, it lost considerable surface intensity but maintained its intensity and high moisture content at higher levels. The trajectory of this storm was along a line farther north than the mid-August storm. Instead of approaching the southern Appalachians near Chattanooga where the ridge is lower, it was directed toward the highest portion of the Blue Ridge which it was unable to cross because of insufficient energy.

Storm Rainfall, General--The storm of July 1916 was accompanied by extremely high rain over South Carolina, western North Carolina, and extreme eastern Tennessee. Although a center of high rainfall in excess of 16 inches was recorded in east-central South Carolina, the general rainfall pattern became heavier in a westerly direction across North Carolina. The heaviest recorded rainfall was found along the divide between the Atlantic and Tennessee River drainage. On this ridge, 22 inches was recorded in 24 hours at Altapass, and a considerable area received over 10 inches. West of the western divide of the upper French Broad watershed, the rainfall rapidly decreased to insignificant amounts.

Storm Rainfall, Upper French Broad Basin--As shown on the isohyetal map for this storm, plate 46, rainfall amounts of about 20 inches occurred along the eastern rim of the area. These amounts decreased westward and northward across the valley and only moderately heavy rains of about 6 inches occurred along the headwaters of the left bank tributaries of the upper French Broad River. The rainfall at Asheville and for some distance up the valley was generally lower than the basin average.

Although there is considerable similarity between the 1916 rainfall pattern and the rainfall distribution in both 1940 storms, this storm is different in that the eastern divide received considerably more rainfall than did the mountains to the west. This resulted because the lower divide produced sufficient orographic lifting of the tropical air in this case to raise it to the level of free convection. In this condition, the bulk of the moisture in the storm was dissipated, leaving insufficient energy to carry the storm westward. This fact is important in showing that the low eastern ridge is perhaps as subject to extreme rainfall as the higher mountains to the west.

The major portion of the flood producing rainfall occurred during a 12-hour period on the night of July 15-16. Asheville is the only station at which hourly intensities were observed during this storm. Since that station received only 2.85 inches during the storm, those low intensities are in no way indicative of those which must have occurred in the high rainfall areas. Along the eastern divide the rainfall averaged over one and one-half inches per hour for twelve hours.

Analysis of Rainfall and Run-off--Rainfall was observed at only four valley and no ridge stations in the upper French Broad. These meager data were insufficient to develop an accurate isohyetal map for the storm. The rainfall pattern could be developed only after a thorough search for additional data on rainfall amounts and duration from other sources, and an analysis of these with records of run-off.

In developing the 1916 rainfall pattern, the French Broad area was divided into the sub-areas shown on the rainfall map, which are the identical units analyzed for the 1940 storms. All available rainfall amounts were located on this map. Rainfall duration was established from the Asheville hourly intensity record, from newspaper and other accounts, and from a study of meteorological data.

High-water profiles of the 1916 flood were utilized to obtain peak gage heights at each gaging station on the French Broad River and the major tributaries. These peak gage heights applied to computed extensions of existing ratings established the peak discharges. With unit graphs of the proper duration developed from previous floods, the necessary run-off in inches to produce these peak discharges was determined. At Rosman, Calvert, and Blantyre, additional gage heights obtained by interview with old residents were a considerable aid in developing the hydrographs. The hydrograph at Asheville was established from a partial gage height record and from observed discharges downstream at Dandridge.

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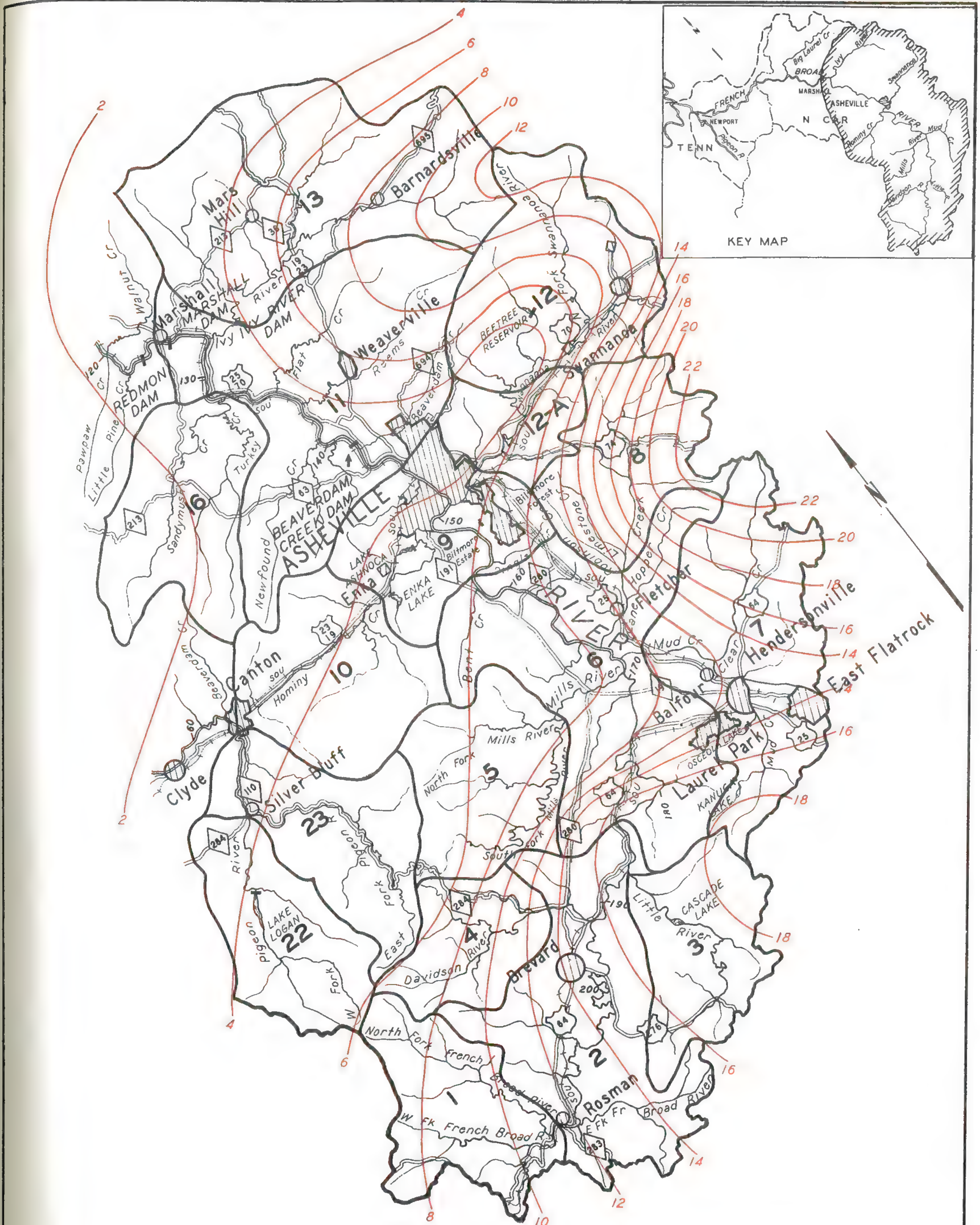
UPPER FRENCH BROAD AREA
SHOWING
LATE AUGUST 1940 STORM RAINFALL



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WATER CONTROL PLANNING DEPARTMENT

UPPER FRENCH BROAD AREA
SHOWING
JULY 1916 ESTIMATED STORM RAINFALL

With the minimum infiltration rates applicable in this case, as developed from the study of the mid-August 1940 flood, it was possible to determine the rainfall. Rainfall equals the run-off plus the infiltration rate times the duration. This procedure was followed for each unit area above Asheville. The combined run-off of the various areas was checked for the French Broad at Blantyre, Bent Creek, and Asheville.

Finally, the rainfall map was drawn to produce a reasonable pattern consistent with the observed amounts, the topography, and the computed average rainfall for each unit area.

Hypothetical Design Storm

As a basis for the design of flood control works to afford complete protection for the city of Asheville, a hypothetical storm of the maximum proportions for the Upper French Broad watershed was developed. In connection with this, Mr. Theodore W. Kleinsasser and Mr. Russell J. Younkin, Meteorologists, U. S. Weather Bureau, Knoxville, Tennessee, consulted with the Authority engineers, assisted in the development of the maximum storm pattern, and reviewed this after it had been developed. Discussion by Mr. Kleinsasser and Mr. Younkin of "Maximum Rains Over Western North Carolina" is given in a succeeding part of this Appendix.

Intelligent study of past rainfall in the Upper French Broad region and of the location, configuration and topography of this watershed in relation to storm paths and potentialities leads to the conclusion that maximum storm rainfall over this region should be determined with all of these considerations in mind and not by some empirical method which may be applicable to other parts of the country. For example, in flat or rolling country of relatively low elevation, the method of transposition of large storm rainfall from an area where such rainfall has occurred to another which is under investigation has been customary. In the Upper French Broad region, the use of this method has no applicability and would give erroneous results excepting perhaps for small drainage basins.

Storm Pattern--Study of the isohyetal maps for the 1916 and 1940 as well as the average annual map clearly indicates a typical rainfall pattern. The area is bounded along the west, south, and east by heavy rain corresponding to the topography. At Asheville and extending for some distance upstream there is an area of low rainfall. In the 1916 storm, extremely heavy rain fell only on the eastern divide. In the 1940 storms, there was heavy rain on both ridges with somewhat higher amounts on the west.

Magnitude of Design Storm--Plate 47 is an isohyetal map of the developed maximum storm. The design storm was assumed to be of hurricane origin and to follow a path similar to the 1916 storm with resulting winds normal to the mountain slopes, a condition necessary for maximum precipitation.

The rainfall amounts between the eastern divide and the French Broad River were assumed substantially as they occurred in 1916. Those

extremely high rainfalls are believed to be about a maximum for that part of the watershed. On the left bank of the river and over the Blue Ridge Mountains, the rainfall was assumed to occur in a pattern similar to those observed for the 1940 floods and the average annual isohyetal maps. The rainfall along the Blue Ridge was made greater than either of the 1940 storms and sufficiently high so that the whole area produced a peak of 154,000 cubic feet per second at Asheville. The peak discharge of 154,000 cubic feet per second corresponds to $5000\sqrt{\text{Drainage Area in Square Miles}}$ which is considered a reasonable maximum.

Based on this design rainfall, a complete flood analysis was made for the various unit areas. The prior run-off conditions for the design storm were assumed similar to those in 1916. That storm was preceded by considerable rain which reduced the infiltration rates to a minimum. The run-offs from the unit areas were combined to produce the hydrograph at Asheville, which has a peak discharge of 154,000 cubic feet per second and a volume of surface run-off equal to 9.19 inches. The flood of 1916, which is the greatest of record, reached a peak of 103,000 cubic feet per second and had a volume of surface run-off of 6.64 inches. The hypothetical design storm therefore provides a margin of approximately 50 percent in both peak rate and volume of surface run-off over the great 1916 storm.

III. RAINFALL IN PIGEON RIVER BASIN

The Pigeon River watershed lies immediately to the west of the Upper French Broad drainage basin. The major flood problems in the Pigeon Basin are those above Canton.

The Upper Pigeon Basin is bordered by high mountains with elevations generally above 5000 feet. Canton, located in the river valley, is about elevation 2600 feet. The high mountain rim around the basin definitely influences rainfall within the basin. The location of the basin to the west of the French Broad also protects it to some extent from the high rainfall to which the Upper French Broad watershed is subjected. In July 1916, for example, when the French Broad Basin experienced the very heavy rainfall which produced its largest flood of record, the Pigeon Basin had comparatively little rain.

Table 2 gives the annual precipitation in the Pigeon River Basin above Canton. This shows that annual rainfall is highest at the stations located on the high divides. Canton, in the valley, has a mean annual rainfall of slightly less than 40 inches which is comparable to that of Asheville. Both of these places have low rainfall for this region because of the sheltering effect of surrounding mountains.

~10~ INCHES RAINFALL

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

UPPER FRENCH BROAD AREA
SHOWING
HYPOTHETICAL MAXIMUM STORM RAINFALL

TABLE 2

ANNUAL PRECIPITATION IN THE PIGEON RIVER BASIN

ABOVE CANTON, NORTH CAROLINA

Station	Elevation Feet	Period of Record Years	Annual Precipitation Mean Inches	Maximum Inches	Year	Minimum Inches	Year
Canton	2600	11	39.35	52.81	1936	27.79	1941
Dix Creek	3500	7	50.40	63.94	1936	34.35	1941
Mt. Pisgah	5300	7	59.01	76.81	1940	46.89	1938
Pink Beds (a)	3300	5	69.83	79.74	1937	51.58	1941
Haywood Gap (b)	5250	7	60.68	77.16	1936	45.82	1941

(a) In French Broad River drainage but near Pigeon River watershed.

(b) In Little Tennessee River drainage but near Pigeon River watershed.

The preliminary engineering studies for flood control on Pigeon River have indicated that flood protection for Canton can be more economically secured by levees than by storage reservoirs. Since levee design is based on peak flow rates rather than volume of flood flow, no detailed study to develop a hypothetical maximum storm for the Pigeon River Basin has been made.

IV. MAXIMUM RAINS OVER WESTERN NORTH CAROLINA

by Theodore W. Kleinsasser and Russel J. Younkin, Meteorologists, U. S. Weather Bureau, Knoxville, Tennessee

In general, there are two types of storms that produce heavy rainfall--the thunderstorm type and the frontal type. Combinations or variations of these two types, intensified by topographic influence, produce maximum storms.

Four prerequisites are essential to the production of a maximum storm over any area, such as western North Carolina. First, the air mass or air masses involved must have a high moisture content. Second, the air mass or air masses involved must have an unstable, or at least potentially unstable, vertical stratification. The factors favoring such a stratification are a steep temperature lapse rate and a high moisture content in the lower levels. Third, the pressure distribution must be favorable to the critical flow pattern for the area under consideration. Such a flow pattern must not only favor the development of an unstable stratification, but also must favor the greatest and most rapid vertical lift. Fourth, the critical flow pattern must be maintained for a considerable period of time.

This is but another way of saying that the displacement of the pressure systems over the country as a whole must be relatively slow.

Let us now consider the factors controlling the first prerequisite--high moisture content. The capacity for holding water vapor depends upon the temperature and pressure. Of these, temperature is by far the most important factor. The capacity for holding moisture increases with temperature. During the summer season, the air temperatures are higher than in the winter. Therefore, the summer season must be considered more favorable to the fulfillment of the first prerequisite.

The summer season is also more favorable to the fulfillment of the fourth prerequisite--slow moving systems. It is a well-known fact that the displacement of pressure systems is much slower in the summer than in the winter, and that at times stagnation of pressure systems occurs. For this reason, it may be expected that once a favorable heavy rain circulation is established in the summer, it will be maintained over a longer period of time than would be the case in the winter.

The prerequisite of unstable stratification of the air mass is fully as important as high moisture content. Flood rains over a relatively large area are the result of sustained large scale overturning of unstable air. If a layer of air is very moist in the lower portion, with the relative humidity decreasing in height within the layer, lifting the layer will cause the temperature lapse rate to steepen. Upon being lifted, the lower portion reaches saturation before the upper portion. Any additional lifting will then release the latent heat of condensation in the lower portion. The lower portion, therefore, will not cool as rapidly as the upper portion. Lifting such a layer, either by frontal or orographic influence, will rapidly cause unstable conditions, large scale overturning, and intense rainfall over the area, as long as the replacement of air of the same characteristics continues.

During the summer months a mass of air moving inland from the Atlantic Ocean will become more unstable. As the air mass moves inland, heat is supplied at the surface and the lapse rate becomes more unstable throughout the lower layers. This maritime air mass is often of polar continental origin, and is found to be relatively dry in the upper levels. This stratification of moisture gives potential convective instability to the air mass. In winter, an air mass moving inland from the Atlantic Ocean will be cooled from below, and the lapse rate will become more stable.

As already stated, the critical flow pattern must not only be favorable to the development of an unstable vertical stratification of the air masses involved, but must also favor the greatest and most rapid vertical lift.

The amount of precipitation released by a column of air is mainly governed by the initial moisture content and the total lift. The intensity of rainfall is largely governed by the rate of lift. The total lift and the rate of lift both depend directly on the trajectory of the air current and the initial stratification of the air column.

A stable stratification of the air column will resist vertical displacement, and will tend to flow around, rather than across, an obstruction, such as a mountain range. An unstable stratification of air will flow across a mountain range without resisting vertical displacement.

An air current undergoing shrinking gains anticyclonic vorticity. This vorticity effect becomes operative in air currents flowing over mountain ranges. As the air current is lifted over a mountain barrier, it shrinks. The vorticity effect will then cause it to be deflected to the right. The angle of attack with respect to the barrier is, therefore, of great significance in determining the rate of lifting.

Figure 1 illustrates the most critical angle of attack for an air current to have the greatest rate of lifting.

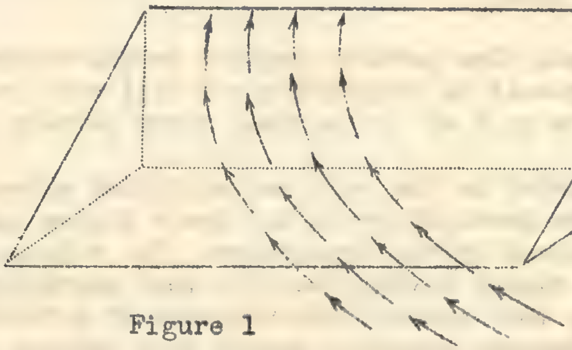


Figure 1

The general orientation of the mountain ranges over western North Carolina is northeast to southwest. An easterly current of air over this area will gain anticyclonic vorticity as it encounters the mountain ranges, and this in turn will produce the greatest rate of lifting.

If the trajectory of the easterly current of air attacking the slopes shows a past history of its flow from Iceland and Newfoundland and over the Atlantic Ocean to the Carolina Coast, this critical flow pattern over North Carolina would be further intensified. The Atlantic Ocean, with its Gulf stream, is favorable to the development of an unstable stratification of the air mass as it flows southward, and eastward from Newfoundland and Iceland. This trajectory of the air allows it to become nearly saturated in the lower portions with a gradual decrease of humidity in the upper portions.

Let us now briefly discuss the pressure distribution, both at the surface and aloft, which would be favorable to the production of a maximum storm over western North Carolina.

The surface map would show a slowly moving, or nearly stationary pressure trough with a north-south, or north-northeast, south-southwest orientation, extending from the Eastern Lake region southward through Tennessee. Relatively high pressure would prevail over the North Atlantic Coast, and also over the Central and Northern Great Plains. With this

pressure distribution, a warm front will usually be found in the east-central states, and a slow moving cold front in the center of the pressure trough. It is important that the surface position of the warm front be to the west and southwest of western North Carolina to produce a maximum storm over that area.

At three kilometers, a well-defined pressure trough with a north-northeast, south-southwest orientation will be found a short distance to the west of the pressure trough on the surface map.

With such a pressure distribution at the surface, and at three kilometers, the circulation would be favorable for a maximum storm. Through the lower levels, up to four thousand feet, the wind would be east to south-east. Above that level, it would veer to the south or south-southwest up to an elevation of ten thousand feet.

Such a critical flow pattern applied to the topography of western North Carolina should result in orographic rainfall with the isohyetal distribution comparative to that of the maximum storm pattern shown on plate 47.

The lift imparted to the east and southeast current will release the potential convective instability in the lower layers and result in a rainfall pattern determined by the topography. The release of potential convective instability at higher levels, where a more southerly component prevails, will result in a more general distribution of rainfall. The relative distribution of total amounts received should then conform closely to the distribution indicated on the maximum storm pattern.

It may be further stated that the maximum storm is most likely to occur during the summer season.

Tennessee Valley Authority
Water Control Planning Department
Geology Division

APPENDIX D

GEOLOGY OF FRENCH BROAD RIVER BASIN

AND

PROPOSED DAM SITES

Knoxville, Tennessee
August 1942

CONTENTS

APPENDIX D

I. GEOLOGY OF THE FRENCH BROAD RIVER BASIN

The master streams in the Southern Appalachian mountains, having long and complicated histories, and flowing in a geologically complex terrain, have developed courses and valleys that deviate widely from the typical or ideal river valley. The valley of the French Broad, and those of its neighbors, especially the Little Tennessee and the Hiwassee, present many striking, but few anomalous, features. Although these streams and their respective valleys are, in the main, quite similar, the French Broad has become the classic example of a Southern Appalachian river.

Geologically, the French Broad Basin is as complex as any area of equal size in the Southern Appalachians. It contains a great variety of rocks and minerals. With respect to age, some of the rocks, especially those in the upper portion of the basin, are among the oldest on the North American continent. Structurally, they are complex, having been repeatedly deformed by mountain-building movements. The structural features exhibit, in the main, northeast-southwest strikes and southeast dips. In their present condition, the rocks are closely folded and intricately faulted. Thrust faults of great magnitude are quite common structural features, and along these structures thick sheets of rock have ridden over subjacent masses for many miles. Many of the rocks have been so thoroughly altered by high temperatures and enormous pressures that their original characters have been completely obliterated, new textures and new minerals being developed at the expense of the old.

On the basis of geology, the basin may be divided into two areas - the area of crystalline siliceous rocks and the area of limestones andd shales. Each of these areas is characterized by differences in geologic structure as well as rock characters.

The area of crystalline siliceous rocks extends from the headwaters in North Carolina downstream to the point where the river emerges from the mountains about two miles upstream from Bridgeport, Tennessee. The rocks of this area consist mainly of gneisses and schists of great variety, granites, quartzites, and slates. In addition to these rocks, there is a small area of unaltered limestone and shale in the vicinity of Hot Springs. Granites are of somewhat limited distribution, being confined mainly to two areas, the headwaters area south of Asheville, and an area just west of Marshall. Gneisses and schists of several varieties occur between the two granite areas, that is, between Fletcher and Marshall. Quartzites and slates, the former being heavily preponderant, occur from a point near Stackhouse to the western margin of the gorge.

Strike faults of the overthrust type and of steep southeast dips are very numerous in the crystalline area. The gneisses, schists, and the quartzites have been compressed into folds, but compression continued until the folds were broken so that the rocks inclined southeastward.

The area of limestones and shales extends from the western margin of the mountains to and beyond the mouth of the river. These rocks are highly deformed, but unmetamorphosed, sedimentary rocks of lower Paleozoic age. Several formations, representing several ages and several variations in composition, are represented. Like the crystalline rocks, the limestones and shales have been thrust-faulted and now occupy a series of overlapping fault blocks of southeast dip. Open folds are to be found, but in general such folds as were formed were finally broken by faulting.

From its headwaters in the Blue Ridge Mountains of North Carolina, the French Broad follows a sinuous northeasterly course to a point near Fletcher, nine miles south of Asheville, where it swings into an equally sinuous northwesterly course across the mountains into the Great Valley of East Tennessee. At a point near White Pines, Tennessee, about twelve miles S 20° E of Morristown, at its confluence with the Nolichucky, it turns abruptly and flows southwestward to near Knoxville, where it unites with the Holston to form the Tennessee.

The Asheville Plain, that portion of the French Broad basin which lies upstream from and to the south of Asheville, is relatively broad, flat, and open. From their sources high in the mountains, the river and its tributaries plunge down steep gradients to the plain, where they lose the steepness of their gradients and flow sluggishly to the north. The immediate valley of the river stands at an elevation of 2000 to 2200 feet and is of very irregular shape ranging in width from less than a mile to several miles. Tributaries, all of which are small and enter the river at grade, add to both its width and irregularity of shape. Mud Creek, which flows northward through Hendersonville and enters the river three miles southwest of Fletcher, gives the low-lying portion of the valley a maximum width of about fourteen miles. In this entire section of the basin, the river and its tributaries are flanked by extensive flood plains ten to fifteen feet thick.

From Asheville to Marshall, the river is incised in a narrow valley to a depth of 200 to 400 feet. In this section the flood plains consist of very narrow marginal flats, and the tributaries have valleys of V-shaped cross sections. The river flows on bedrock, and rapids and ripples are characteristic of the entire section.

Near Marshall, the stream enters a precipitous gorge, 400 to 1000 feet deep, from which it emerges about two miles upstream from Bridgeport, Tennessee. The gorge section is characterized by rapids, low waterfalls, and marked variations in the width of the channel. Tributaries, likewise flowing in precipitous gorges, enter at or very near grade.

From near Bridgeport to its confluence with the Holston near Knoxville, the river has a very gentle gradient and is characterized by a broad, comparatively flat valley. It has extensive flood plains, as have also the numerous tributaries, large and small.

The evolution of the present French Broad basin forms a fascinating story. In Cretaceous times, several million years ago, the Southern Appalachians were worn down by erosion to a low-lying and comparatively flat terrain. The surface of this terrain was, in places, interrupted by erosional

remnants - residual masses at divides which had not been reduced to the low level of the Cretaceous plain. Some of the remnants of a former higher terrain were of mountainous proportions, and have been given the name "Unakas" because of their excellent development in the Southern Appalachians. Mount Pisgah and some of the higher peaks along the margins of the present valley are remnants of the older surface.

On the Cretaceous erosional plain, the French Broad and its larger tributaries and its neighbors flowed sluggishly, developing meanders, and constantly shifting their channels. At this stage in its history, the position of the river's channel was not at all influenced by the character of the underlying rock, for even the hard rock was deeply decayed and the river was so near base level that it was impotent to accomplish further erosion. Then slowly, perhaps over a period of millions of years, the area was uplifted. As soon as the uplift was felt by the river, it began to entrench itself in the channel it then occupied. It so happened that at the time the uplift was first felt by the river, it was completely out of adjustment with the geology. Far from being aligned on zones of weak rock, its course was across the strike and therefore across very hard, as well as very soft, rocks. By virtue of its newly acquired erosive power, the river soon entrenched itself to reasonably sound rock, which may have been as much as a few hundred feet. As uplift was continuing, the stream continued uninterruptedly to deepen its channel, without an opportunity to shift its course to softer rock. This condition is strikingly attested by the fact that, south of Asheville, it flows for miles on the hard Henderson granite, parallel and closely adjacent to the soft and structurally weak Brevard schist.

The rocks rich in feldspar, mica, and hornblende have been much more susceptible to decay than the quartzites, which are composed nearly entirely of quartz. For this reason, the portion of its valley upstream from Marshall is much broader and more mature than in the very stable and very resistant quartzites farther downstream. The limestones and shales in the Great Valley area, being rather non-resistant rocks, permitted the river to develop the lower portion of its valley rapidly, so that it does not differ materially from the Holston-Tennessee Valley.

II. GEOLOGY OF DAM SITES IN THE UPPER FRENCH BROAD BASIN

The upper portion of the French Broad basin is an area of lithologic diversity and structural complexity. From Stackhouse, North Carolina to the upstream extremity of the basin, pre-Cambrian crystalline rocks of igneous and metamorphic origin are predominant. In this area, the rocks consist mainly of gneisses and schists of many types, although large areas of more or less altered granites occur. These rocks are divided into several formations, of which the Carolina gneiss, Roan gneiss, Henderson granite, Whiteside granite, and Brevard schist are the most extensively developed in the area. All of these formations are characterized exclusively by siliceous rocks, except the Brevard schist which contains extensive limestone members.

All of the rocks in the upper French Broad basin have been deformed structurally. Faults of both major and minor structural significance

are exceedingly numerous. These structures are, almost without exception, thrust faults of northeast-southwest trend and southeast dips. The layered rocks, especially the gneisses and schists, are sharply folded and contorted. All of the rocks are more or less schistose, and schistosity trending in northeast-southwest directions and dipping to the southeast. Joints of several types are extensively developed in all of the rocks of the area.

Nearly all of the rocks of the upper French Broad basin are excellent for dam site purposes. All of the granites and gneisses and most of the schists are sufficiently strong and substantial to support any engineering structure that might be brought to bear upon them. Some of the schists, however, are very weak rocks.

The Brevard schist, which has a highly schistose texture in which the schistose surfaces are geometric planes, is a very weak rock. It has a very low bearing strength and even lower resistance to shearing stresses. In addition to its physical weakness, the formation contains limestone beds which are likely to be cavernous. On the other hand, the schist is tight and impervious and should be entirely satisfactory in the foundations of earth and rock fill dams, provided the limestone members are either absent or are treated to prevent leakage.

The foundation problems likely to be encountered in the other formations of the area are those involving geologic structure and deep rock decay. Faults, although generally obscure, are quite numerous and may occasion considerable difficulty in the preparation of dam foundations, and, if overlooked or ignored, may facilitate leakage or cause failure. Joints, which are very abundantly developed in all of the rocks of the area, are of several kinds, but "sheet joints" (those developed in consequence of weathering and unloading by erosion, and which are roughly parallel to the topographic surface) and "strike" and "dip" joints (those trending parallel to the strike and dip respectively, of the rock) are most numerous. Joints, by permitting the ingress of water, promote deep decay and are to be regarded as leakage hazards, unless the weathered rock is removed and the remaining joints effectively sealed by grouting. Schistosity may present the same problems, especially in mica schists. On gentle slopes, in saddles, and at the crests of ridges the overburden of residual earth may be as much as a few hundred feet thick.

For small earth and rock fill dams, most of the dam sites in the upper French Broad basin are entirely satisfactory. In the case of reservoirs to be filled for very short periods of time at rather infrequent intervals, extensive foundation treatment programs are unnecessary. Sites containing limestone members should be thoroughly explored by drilling in order to determine whether the cavities are sufficiently large, open, and near the surface to cause caving of the surface and the failure of the dam.

The geologic conditions at the individual dam sites are described in the following paragraphs.

AZALEA DAM SITE

Geology

The Azalea dam site on the Swannanoa River, and nearly all of the reservoir site as well, is on rocks of the Carolina Gneiss Series (plate 48-A). Locally, the series consists mainly of typical regularly banded granitic gneiss of light gray color and slightly banded gneiss of dark gray color. These rocks are cut indiscriminately by dikes of alaskite granite and by veins of white quartz.

Although northeast strikes and southeast dips prevail in the general vicinity of the dam site, marked variations in the geologic structure occur. In places, the rock is closely folded and sharply contorted; consequently wide differences in structure occur within very short distances. In outcrops in the left abutment, the gneissic layers have strikes of about N 85° W and dips averaging 28 degrees northeast. An outcrop of highly contorted rock in the right abutment exhibits a wide diversity in both strike and dip. The stripping of the overburden from the dam site would undoubtedly reveal an extremely complex geologic structure characterized by wide differences in the direction of the strike and in the direction and angle of the dip.

Joints of several types are extensively developed in the rock at the dam site. In the weathered and partially decayed rock they are sufficiently open to occasion leakage; in sound rock they are tight, but may be opened somewhat by blasting.

At the dam site, the river is flowing on bedrock, or on a thin layer of sand and gravel which immediately overlay it. As there are no flood plains, the overburden in the valley floor is negligible.

The rock in the right abutment is nearly everywhere concealed by a blanket of residual earth. Although the average thickness of the earth overburden is perhaps not great, the rock surface is likely to be quite irregular. The total overburden of earth and decayed rock will probably average between 10 and 15 feet. An outcrop just downstream from the axis extends from the water's edge to a height of about 25 feet. Very little overburden is to be expected in the lower 20 or 30 feet of this abutment.

In the left abutment, ragged outcrops of irregular outline occur from near the base of the slope up to about 75 feet above the river. The rock surface is, no doubt, very irregular and the average thickness of the overburden of earth and decayed rock may be several feet thick.

Materials

Nearly all of the unweathered rock in the vicinity of the dam site is entirely suitable for use in either concrete or rock fill. Good quarry sites, however, are rare. The best quarry site found is about 4000 feet upstream on the left side of the river in the middle section of a sigmoidal curve in stream's course. This quarry would probably yield 75,000 to 100,000

cubic yards of rock, although the overburden may be quite thick back from the river. Other quarry sites of similar size and quality occur farther upstream.

There are no large bodies of obviously suitable earth near the dam site. The hills and ridges which stand 100 to 200 feet above the river are capped by thick deposits of residual earth. The material contains rock fragments of various sizes and for this reason it may prove to be unsuitable for use. An ample quantity of suitable material could perhaps be located within reasonable distance of the dam site.

Summary

In the main, the Swannonoa dam site is quite suitable for a rock and earth dam 142 feet high. The establishment of a satisfactory cut-off will entail trenching through the zone of badly decayed rock and some grouting in the more sound rock below. Solution channels and other openings which could serve as conduits for leakage are not present in any of the rocks involved in the site. Materials are available in the area, although no ideal quarry sites or borrow pits have been located.

BURNEY MOUNTAIN DAM SITE

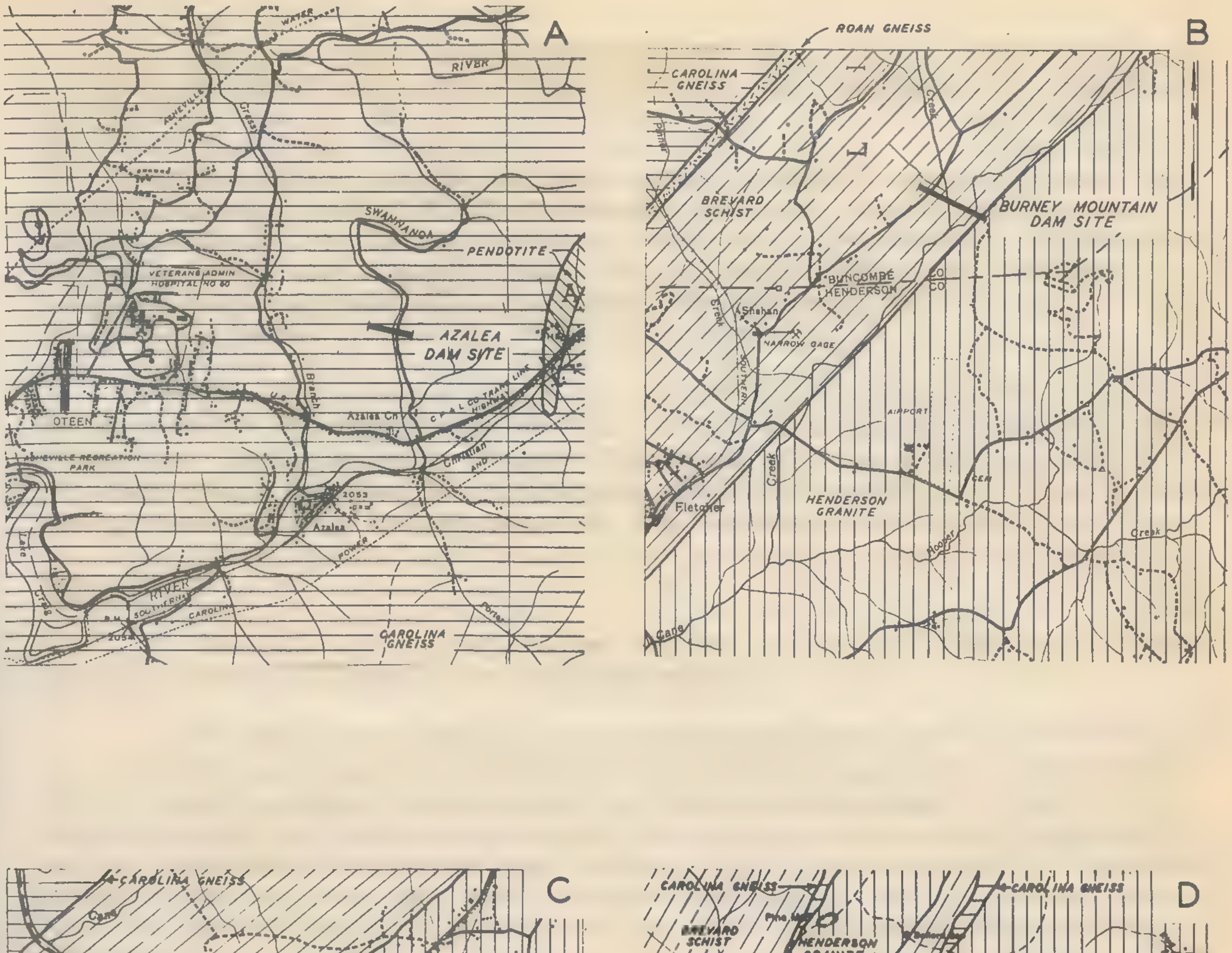
Geology

The Burney Mountain dam site on Cane Creek is on both the Henderson granite and the Brevard schist (plate 48-B). Locally, the Henderson "granite" is an augen gneiss. The Brevard schist is a very fine-grained, dark colored mica schist. Included within the Brevard formation is a limestone bed 40 to 200 feet thick which is worked for lime a short distance southwest of the dam site. Although the contact between the two formations cannot be definitely determined from surface evidence, it seems to be at the base of the left abutment.

The geologic structure is very largely obscured by the flood plain alluvium along the two creeks. In the left abutment, where the Henderson granite forms a bold bluff, the schistosity strikes in average direction of N 50° E and dips to the southeast at an average angle of 47 degrees. Elsewhere in the area, the Brevard schist has about the same strike and dip as that of the granite and the same may be presumed to be the case at this locality.

Joints are extensively developed in the Henderson granite. A majority of them have northeast strikes (N 50° to 60° E) and southeast dips of about 75 degrees. Another set of joints has a trend of about N 10° W, and is vertical, or essentially so.

From the left margin of the flood plain up to an elevation about a hundred feet higher, the left abutment is quite steep. Exposures of bedrock occur along the base of the cliff and on the abutment up to a point about 50 feet higher. The earth overburden is thin, and it is unlikely that there is any appreciable thickness of decayed rock.



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TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

GEOLOGY OF DAM SITES
UPPER FRENCH BROAD BASIN

The creek and flood plain areas are underlaid by schist, the elevation of the rock surface being about the same as that of the bottom of the stream channel. The flood plain deposit is about 10 feet thick and consists principally of fine silt. The schist, per se, is perhaps sound a short distance below the top of rock, but if limestone bed is present, as it almost certainly is, solution channels are to be expected to depths of a hundred feet. A few well placed drill holes will be necessary in order to determine where the limestone bed is and to what depth it is cavernous. Large filled or largely filled cavities communicating with the surface could conceivably result in failure, partial or complete.

The right abutment is a low, gently sloping hill in mica schist. No exposures of bedrock occur, but the surface contains numerous platy schist fragments. Decay is rather deep in this abutment, and a small amount of drilling should be done for the purpose of determining the position of sound rock, and the amount and character of the weathered material.

Materials

The flood plains of the two creeks contain an abundance of earth which is probably suitable for fill material.

The Henderson granite on the southeast margin of Cane Creek valley is excellent rock, suitable for use in rock fill or concrete. Good quarry sites are not numerous in the area, but the required amount of rock fill material could no doubt be obtained within a mile or two of the dam site. To the northwest of the Cane Creek valley, there is a large belt of granitic gneiss which has long been used as a building stone. It is suitable for rock fill and riprap, but it contains too much coarse mica to be used in concrete.

Summary

The Burney Mountain dam site is satisfactory for a rock and earth dam 68 feet high, but the presence of cavernous limestone should be determined by drilling. Drilling would also afford necessary information as to the amount of grouting necessary.

NAPLES DAM SITE

Geology

The Naples dam and reservoir sites on Mud Creek are on the Henderson granite formation (plate 48-C). Locally, the Henderson formation consists of a slightly altered coarsely crystalline granite which is more appropriately called an "augen" gneiss. The planes of schistosity have northeast strikes and southeast dips.

The rock is quite massive in character, but it is cut by numerous joints of several types. Because of the jointing, the upper few feet of bedrock are likely to be somewhat unsound. Although estimates as to the

thickness of the overburden have not been made, a considerable thickness of overburden is to be anticipated in the foundation and abutment areas.

Materials

Materials suitable for use in the dam are available in the vicinity of the dam site. The flood plain alluvium along the French Broad River and Mud Creek is undoubtedly excellent for use in the fill. Residual clay overlying the granite on the higher hills should also be satisfactory for use in the fill. The Henderson granite, wherever found, is excellent for riprap, rock fill, and concrete aggregate.

Summary

The Naples dam site is entirely satisfactory for an earth fill dam 48 feet high. The only problems the site presents involve the establishment of a cut-off through the overburden and the proper selection of fill material.

PENROSE DAM SITE

Geology

The Penrose dam site on Little River and the reservoir area are on the Henderson granite formation (plate 48-D). The rock is a pre-Cambrian prophyritic granite which has been altered to an "augen" gneiss. It differs from a true granite only in the distortion of the large feldspar crystals and the presence of a slight schistosity.

Structurally, the rock is of massive character. The planes of schistosity, which are textural rather than structural, exhibit northeast strikes and southeast dips. The rock is likely to be openly jointed, especially near the surface.

The only geologic problems to be encountered in dam sites on the Henderson granite are those resulting from the overburden and the unsoundness of the upper portion of rock. Joints are ubiquitous in the rocks of the area, and are undoubtedly responsible for some unsound rock at the Little River dam site.

Materials

There is an abundance of flood plain earth in the valleys of the larger streams in the vicinity of the dam site. The higher hills also contain appreciable thicknesses of residual earth. There is no question as to the availability of an ample quantity of suitable material for earth fill within a short distance of the dam site.

Summary

The site is entirely suitable for an earth dam of the height for which it is considered.

CATHEYS CREEK DAM SITE

Geology

The Catheys Creek dam site and the reservoir are both on the Henderson granite formation which consists, locally of a granitoid ("augen") gneiss (plate 49-A). The rock is very similar to a true granite from which it differs only in the distortion of the large feldspar crystals and a slight schistosity induced by metamorphism and deformation.

The rock is of massive character and exhibits none of the weaknesses of a stratified formation. Planes of schistosity which are of textural rather than structural significance exhibit northeast strikes and southeast dips. Joints of several kinds are undoubtedly present in the upper few feet of rock.

The Henderson granite is an excellent rock for dam sites. It presents few and simple problems, the most of which are related directly to overburden conditions and to unsoundness in the upper few feet of rock.

Materials

Although no field work has been devoted to the location of construction materials at the Catheys Creek dam site, there should be an adequate quantity of both rock and earth within a reasonable distance. The rock of the Henderson granite is excellent for fill material, riprap, and concrete aggregate. The alluvial and residual materials of the area should be entirely satisfactory for fill material.

Summary

The Catheys Creek site should be entirely satisfactory for a rock fill dam, an earth fill dam, or a combination rock and earth dam of the height for which it is considered.

DAVIDSON RIVER DAM SITE

Geology

Both the dam site and reservoir area are on rocks of the Carolina Gneiss Series (plate 49-B). Locally, the Carolina gneiss consists nearly entirely of light gray, fine-grained, faintly banded gneiss and light gray, medium-grained, coarsely and regularly banded granitic gneiss.

Although the rock is deformed, its massive character and competency have locally served to minimize the effects of structural deformation. Faults, though present, are of little consequence in the Carolina gneiss of this area. The upper few feet of rock are extensively jointed, but many of the joints are incipient structures along which the rocks break upon blasting.

At the dam site, the average strike of the gneiss is about N 35° E and the average dip is about 50 degrees to the southeast (downstream). In

general, rock is covered by residual material on the abutments. A few exposures in the road cuts on either side of the river indicate that the upper surface of bedrock is very irregular. The joints in the rock are mostly of northwest strike and steep northeast dip. A rather large quarry just upstream from the dam site on the right bank of the river exposes a considerable face of sound rock in which the joints are tight and practically unweathered. The sheet joints, which are roughly parallel to the top of rock, are present only in the upper few feet of rock.

Materials

There is an abundance of alluvial material in the flood plain deposits on the southeast side of State Highway No. 280 within half a mile downstream from the dam site. This material appears to be excellent for use in an earth fill.

The rock quarry just upstream from the right abutment is adequate to yield as much rock as might be required at the project. It could be considerably extended both upstream and into the mountain. It might possibly yield enough rock to build a concrete dam without affecting the dam site.

Summary

The Davidson River dam site is satisfactory for a dam, of any type, to any height which is feasible.

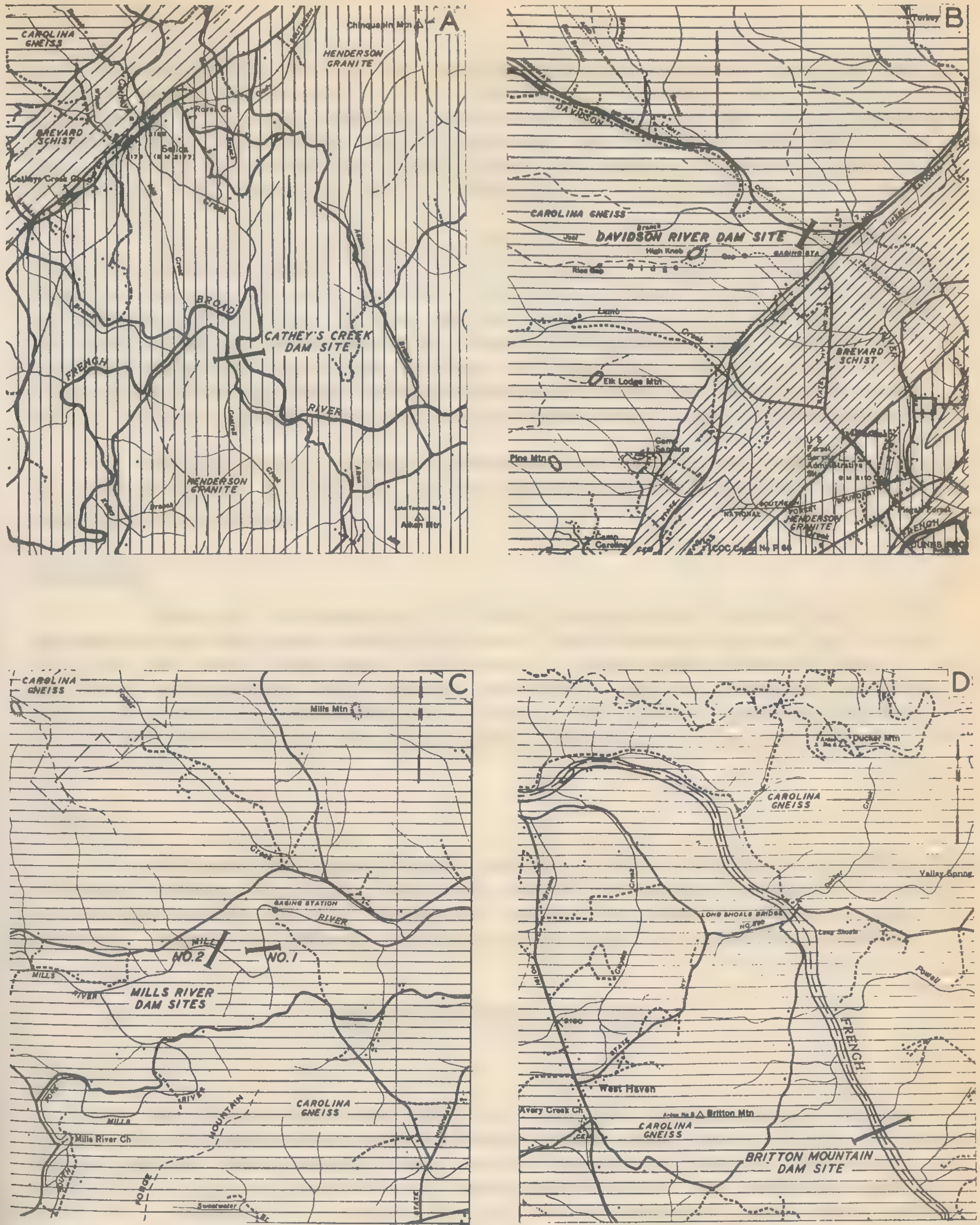
MILLS RIVER DAM SITE

Geology

The dam site and the reservoir area are on rocks of the Carolina Gneiss Series (plate 49-C). Locally, the Carolina gneiss consists of light gray to dark gray banded gneiss intruded by dikes of white alaskite granite and veins of white quartz. Much of the gneiss is regularly and conspicuously banded, but some of it is fine-grained and but slightly banded. Beds of mica schist occur interlayered with the gneiss.

Structurally, the rock is deformed but, due to its competency and its massive character, it is not extensively faulted. The banding, which was developed in the zone of flowage rather than the zone of fracture, exhibits northeast-southwest strikes and steep southeast dips. It is locally sharply contorted, however, and strikes and dips differ radically within a few feet. Joints are numerous in the upper few feet of bedrock, and are usually marked by some rock decay. Sheet joints -- structures parallel to the top of rock -- are likely to be well developed and marked by seams of rotten rock, especially near the top of rock.

The dam site (No. 1) is in the middle section of a sigmoidal curve in the stream's course. The river is flowing on bedrock. The right abutment is a steep, but not precipitous, heavily wooded slope which ascends to an elevation of about 100 feet. Bedrock is covered by an undetermined thickness of residual material and talus. The left abutment is separated



Scale 0 2000 4000 6000 8000 Feet

TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

GEOLOGY OF DAM SITES
UPPER FRENCH BROAD BASIN

from the river by a flood plain approximately 125 feet wide and standing about 10 feet above the bed of the channel. The abutment is fairly steep up to an elevation 35 to 40 feet above the flood plain, the slope becoming progressively gentler above this elevation. It attains an elevation of about 90 feet above the bed of the river. No rock is exposed in this abutment and the thickness of the overburden is undetermined.

A second site (No. 2), approximately 0.4 mile upstream, would require a somewhat longer dam. The left abutment ascends from the water's edge to a height of about 80 feet. Bedrock is exposed from the bottom of the channel, up to 25 or 30 feet on the slope at the upstream extremity of the hill in which the abutment is located. Elsewhere it is covered by residual material. The right abutment is separated from the river by a flood plain standing about 10 feet above the river, and 200 feet or more wide. It is a fairly steep wooded slope and there is no bedrock exposed.

The only rock exposed at this site is a gray, fine-banded gneiss. The "bands" strike N 25 to 35° E, and dip from 35 to 70 degrees to the southeast (downstream).

Materials

There is an abundance of flood plain material within half a mile of each of the dam sites on Mills River. This material appears to be suitable for use in an earth dam. There are no good quarry sites in the immediate vicinity of either of the dam sites. The hill forming the left abutment of the dam site farthest upstream (No. 2) may prove to contain enough satisfactory rock for construction purposes in case Dam Site No. 1 is selected.

Summary

The geologic conditions at either of these sites are favorable for the construction of an earth and rock dam 90 feet high. A cut-off should be carried through the overburden and through the slabby, openly jointed bedrock. Bedrock is strong, siliceous, and free from solution cavities.

BRITTON MOUNTAIN DAM SITE

Geology

The Britton Mountain dam site is on the Carolina gneiss (plate 49-D). The formation consists of typical light gray, more or less regularly banded gneiss. Structurally, the rock is sharply folded and contorted. Although the regional structure of northeast strikes and southeast dips tends to prevail in the general vicinity of the dam site, very sharp local variations in the structure occur. Joints are extensively developed throughout the Carolina gneiss. The close and regular spacing of these structures, in conjunction with their persistence, will undoubtedly account for much unsound rock.

Thick overburden of earth and unsound rock is likely to be encountered, especially in the abutment areas. Core drilling will be necessary for the precise determination of the thickness and character of the overburden.

Materials

The Carolina gneiss is, in general, a satisfactory material for concrete aggregate. A quarry site in good rock can probably be located within a reasonable distance of the dam site.

Summary

The Britton Mountain dam site is satisfactory for a 70-foot concrete gravity type dam. The most serious foundation and abutment problems will be those involving deep rock decay. On the basis of the Authority's experience elsewhere in the area of crystalline rocks, deep excavation and extensive grouting will be necessary to insure watertightness and safety at this dam site.

Tennessee Valley Authority
Water Control Planning Department
Project Planning Division

APPENDIX E

SUMMARY

OF

ESTIMATED COSTS FOR FLOOD CONTROL WORKS

Knoxville, Tennessee
August 1942

CONTENTS

APPENDIX E

SUMMARY

OF

ESTIMATED COSTS FOR FLOOD CONTROL WORKS

Basis for Estimates

Preliminary cost estimates of the flood control structures covered in the report are given in the following tabulation. These estimates are based on the assumption that the work will be undertaken after the war and that 1940 prices will prevail at the time of construction. With this assumption, they are believed to provide an adequate basis for an appropriation request. If 1940 prices do not prevail at the time of appropriation request, the estimates should be adjusted accordingly.

Advance sheets of USGS-TVA topographic maps having a scale of 1 inch = 2000 feet and contour intervals of 20 and 40 feet were used in laying out the eight dam structures and in making quantity estimates. No detailed topographic information was available, and it was necessary to do considerable interpolating, particularly where contour intervals were large. More complete data were available, however, for the Asheville and Hominy Creek levee layouts.

These reservoirs are designed to act as detention basins and consequently will have water in them only at times when stream flow is greater than the capacity of the regulating structures. Spillway levels will be reached only at rare intervals, and the principal function of the spillways is that of protection for the dams. Because of the infrequency and shortness of the period of use, the freeboard under the most extreme flood flow conditions was limited to five feet. For the same reason, the spillway channels were excavated and protected only far enough to insure safety of the structures. In these respects the dams differed from TVA standards for multi-purpose dams, although slopes and typical sections conformed to usual practice. The specific type of dam finally adopted will depend upon detailed information which would be obtained prior to construction.

Depths of overburden and condition of the underlying rock were estimated as a result of field trips to most of the dam sites. No foundation explorations were made, however, and the actual subsurface conditions may differ somewhat from those assumed. The extent of necessary treatment cannot be determined until more thorough investigations are made. The estimates provide for a minimum amount of treatment since dams built to create detention reservoirs do not require extensive foundation treatment.

Unit costs were based on the assumption that 1940 prices would prevail at the time of construction. Several of the unit costs for specialized work such as drilling were predicated upon one contractor, or subcontractor, having the contract for two or more of the dams. Otherwise, the cost of moving equipment into and out of the territory would increase the unit cost of such work.

The estimates for dams and reservoirs provide for acquisition of all buildings below spillway level and flood easements on land to the same elevation. Estimated highway costs in each case cover only the minimum relocation or construction necessary to replace sections of road that would be obstructed by the dam.

SUMMARY

OF

ESTIMATED COSTS FOR FLOOD CONTROL WORKS

UPPER FRENCH BROAD RIVER

		Total Estimate
REGIONAL PLAN		
Azalea Reservoir on Swannanoa River	$1,350,000	
Burney Mountain Reservoir on Cane Creek	1,225,000	
Naples Reservoir on Mud Creek	1,135,000	
Penrose Reservoir on Little River	725,000	
Catheys Reservoir on French Broad River	1,275,000	
Davidson River Reservoir	790,000	
Mills River Reservoir	1,100,000	
Asheville Local Flood Protection--French Broad River	510,000	
Swannanoa River Channel Improvements--Lump Sum	50,000	
French Broad River Channel Improvements--Lump Sum	50,000	
Total - Regional Plan - - - - - - - - - - - - - - - - -		$8,210,000
LOCAL FLOOD PROTECTION (Complete Protection)		
Marshall--French Broad River		767,000
Canton--Pigeon River 10 Feet Above 1940 Flood		172,000
Hominy Creek--Near Enka, N. C.		114,000
TOTAL -		$9,263,000
ALTERNATE PLAN--ASHEVILLE ONLY FLOOD PROTECTION		
Azalea Reservoir on Swannanoa River	$1,350,000	
Britton Mountain Reservoir on French Broad River	3,000,000	
Local Protection Works on French Broad River	403,000	
Swannanoa River Channel Improvements	50,000	
TOTAL -		$4,803,000
ALTERNATE PLANS--LOCAL FLOOD PROTECTION		
Marshall--Protection Equal to 1916 Flood		$ 516,000
Marshall--Protection Equal to 1940 Flood		$ 297,000
Canton--Five Feet Above 1940 Flood		$ 101,000

REGIONAL PLAN

AZALEA RESERVOIR ON SWANNANOA RIVER

ESTIMATED COST

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Main Embankment					
Foundation Exploration and Treatment		L.S.		$ 12,500	
Diversion and Care of Water		L.S.		15,000	
Excavation--Earth and Stripping	58,430	cu. yd.	0.32	18,700	
Excavation--Rock	800	" "	8.00	6,400	
Clearing and Grubbing	10	acre	300.00	3,000	
Concrete--Trench	1,840	cu. yd.	20.00	36,800	
Drainage--Tile and Blanket				14,500	
Rolled Fill--Earth	379,325	cu. yd.	0.29	110,000	
Rock Fill--Quarry Fines	32,150	cu. yd.	2.00	64,300	
--Small Rock	14,100	cu. yd.	2.00	28,200	
--Quarry Run Rock	214,000	cu. yd.	0.90	192,600	
Total Main Embankment -					$502,000
2. Spillway					
Stripping, Grubbing, and Earth Excavation				5,900	
Unclassified General Excavation	110,000	cu. yd.	1.00	110,000	
Concrete	982	cu. yd.	25.00	24,550	
Cut-off--Steel Sheet Piling	5,800	sq. ft.	1.50	8,700	
Rolled Fill	700	cu. yd.	0.50	350	
Gravel Blanket	250	cu. yd.	2.00	500	
Riprap	700	cu. yd.	3.00	2,100	
Foundation Exploration and Cleanup				1,900	
Total Spillway -					154,000

REGIONAL PLAN

AZALEA RESERVOIR ON SWANNANOA RIVER

ESTIMATED COST
(Continued from the preceding page)

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
3. Outlet Conduits					
Excavation--Earth	4,050	cu. yd.	0.30	$ 1,220	
--Rock, Conduit	5,550	cu. yd.	5.50	30,525	
--Rock, Forebay and Outlet	1,339	cu. yd.	3.50	4,685	
Concrete--Walls and Paving	1,647	cu. yd.	25.00	41,175	
--Barrel,Slab,etc.	2,390	cu. yd.	30.00	71,700	
--Floor and Weir	169	cu. yd.	15.00	2,535	
Gravel Fill--Conduit	4,030	cu. yd.	3.50	14,100	
--Forebay and Tailrace	571	cu. yd.	2.50	1,428	
Stone and Riprap	83	cu. yd.	4.00	332	
Foundation Joints and Cleanup				4,300	
Total Outlet Conduits					$ 172,000
4. Reservoir Adjustments (Houses)					25,000
5. Highway, Railroad, and Utility Relocation					--
6. Land and Land Rights					94,000
Total Direct Cost					$ 947,000
Access Road					25,000
Contingencies, Engineering, and Administration					378,000
Total Project Cost					$1,350,000

REGIONAL PLAN

BURNEY MOUNTAIN RESERVOIR ON CANE CREEK

ESTIMATED COST

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Main Embankment					
Foundation Exploration and Treatment		L.S.		$ 13,000	
Diversion and Care of Water		L.S.		600	
Clearing and Grubbing	2	acre	300.00	600	
Earth Excavation and Stripping	50,677	cu. yd.	0.33	17,000	
Rock Excavation--Trench	3,900	cu. yd.	8.00	31,200	
Concrete Cut-off Wall	728	cu. yd.	25.00	18,200	
Trenching, Backfilling, and Tile				4,015	
Stone and Filter Backfill	12,000	cu. yd.	2.50	29,985	
Rolled Earth Fill	484,620	cu. yd.	0.30	145,500	
Gravel Fill	8,300	cu. yd.	2.00	16,600	
Rock Fill	26,330	cu. yd.	3.00	79,000	
Grassing and Sodding				20,300	
Total Main Embankment -					$376,000
2. Spillway and Outlet Conduits					
Foundation Exploration and Treatment		L.S.		7,000	
Diversion and Care of Water		L.S.		5,300	
Clearing and Grubbing	2	acre	300.00	600	
Earth Excavation	20,022	cu. yd.	0.30	6,000	
Rock Excavation	6,424	cu. yd.	3.00	19,300	
Stone Backfill	100	cu. yd.	4.00	400	
Final Cleanup				550	
Concrete--Light Walls	98	cu. yd.	33.00	3,230	
--Retaining Walls (Heavy Reinforced)	9,770	cu. yd.	12.00	117,300	
--Mass	5,558	cu. yd.	12.00	66,700	
--Pavement	1,193	cu. yd.	15.00	17,900	
--Bridge	30	cu. yd.	40.00	1,200	
--Piers	141	cu. yd.	25.00	3,570	
Joints, Stops, etc.				6,000	
Gates and Operating Units (2 ea.)				31,000	
Guard Rail	250	lin. ft.	4.00	1,000	
Total Spillway -					287,000

REGIONAL PLAN

BURNEY MOUNTAIN RESERVOIR ON CANE CREEK

ESTIMATED COST
(Continued from the preceding page)

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
3. Outlet Conduits (See Item 2, Spillway and Outlet Conduits)					
4. Reservoir Adjustments (Houses)					$ 8,000
5. Highway, Railroad, and Utility Relocation					
Highway Relocation				$106,000	
Railroad and Utility Relocation				--	
Total Highway, Railroad, and Utility Relocation					106,000
6. Land and Land Rights					82,000
Total Direct Cost					$ 859,000
Access Road and Camp					25,000
Contingencies, Engineering, and Administration					341,000
Total Project Cost					$1,225,000

REGIONAL PLAN

NAPLES RESERVOIR ON MUD CREEK

ESTIMATED COST

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Main Embankment and Saddle Dam					
Main Embankment					
Foundation Exploration and Treatment		L.S.		$ 6,716	
Diversion and Care of Water		L.S.		10,000	
Earth and Stripping Excavation	39,790	cu. yd.	0.33	13,300	
Rock Excavation--Trench	4,470	cu. yd.	8.00	35,800	
Clearing and Grubbing				450	
Trench Concrete	835	cu. yd.	25.00	20,900	
Drainage Tile and Blanket				32,500	
Rolled Fill	263,510	cu. yd.	0.30	79,000	
Stone Blanket	6,117	cu. yd.	2.00	12,234	
Riprap and Rock Fill	19,706	cu. yd.	3.00	59,200	
Grassing and Sodding	22,800	sq. yd.	0.75	17,100	
Total Main Embankment				287,200	
Saddle Dam					
Stripping	5,100	cu. yd.	0.35	1,800	
Rolled Fill	16,600	cu. yd.	0.30	5,000	
Total Saddle Dam				6,800	
Total Main Embankment and Saddle Dam - - - - - - - - - - - - - - - -					$294,000
2. Spillway					
Foundation Exploration and Treatment	Allowance			5,000	
Clean-up				440	
Clearing and Grubbing	4	acre	300.00	1,200	
Stripping and Earth Excavation	73,700	cu. yd.	0.27	19,750	
Excavation--Rock	15,000	cu. yd.	2.00	30,000	
Backfill--Rock	485	cu. yd.	2.50	1,210	
Concrete--Mass	1,350	cu. yd.	14.00	18,900	
--Paving	1,220	cu. yd.	15.00	18,300	
--Walls (Retaining)	1,425	cu. yd.	25.00	35,600	
--Core Wall	18	cu. yd.	33.00	600	
Total Spillway -					131,000

REGIONAL PLAN

NAPLES RESERVOIR ON MUD CREEK

ESTIMATED COST
(Continued from the preceding page)

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
3. Outlet Conduits and Intake Structures					
Outlet Conduits					
Earth Excavation	7,850	cu. yd.	0.30	$ 2,355	
Rock Excavation--Conduit	510	cu. yd.	5.50	2,800	
--Tailrace & Forebay	1,859	cu. yd.	3.50	6,505	
Backfill--Earth	252	cu. yd.	0.50	126	
--Rock	197	cu. yd.	2.50	492	
Foundation Preparation and Treatment	Allowance			3,000	
Joints and Stops				422	
Concrete--Walls & Pavement	1,634	cu. yd.	25.00	40,800	
--Floor & Weir	446	cu. yd.	15.00	6,700	
--Barrel	1,480	cu. yd.	30.00	44,400	
Total Outlet Conduits				107,600	
Intake Structures					
Foundation Exploration and Treatment	Allowance			774	
Excavation--Earth	343	cu. yd.	0.50	172	
--Rock	147	cu. yd.	4.00	590	
Backfill	47	cu. yd.	0.50	24	
Concrete--Mass	753	cu. yd.	20.00	15,100	
--Piers and Deck	147	cu. yd.	25.00	3,670	
--Reinforced	118	cu. yd.	40.00	4,720	
Joints, Stops, Gates, Bridge and Electrical				44,750	
Total Intake Structures				69,800	
Total Outlet Conduits and Intake Structures - - - - - - - - - - - -					$177,400
4. Reservoir Adjustments and Road Surfacing					
Reservoir Adjustments				35,000	
Road Surfacing					
Other Permanent Roads and Bridges	300	sq. yd.	2.00	600	
Pavement (Incl. Drains)	3,000	sq. yd.	1.50	4,500	
Total Road Surfacing				5,100	
Total Reservoir Adjustments and Road Surfacing - - - - - - - - - - -					40,100

REGIONAL PLAN

NAPLES RESERVOIR ON MUD CREEK

ESTIMATED COST
(Continued from the preceding page)

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
5. Highway, Railroad, and Utility Relocation					
Highway Relocation				$11,500	
Railroad and Utility Relocation				15,000	
Total Highway, Railroad, and Utility Relocation					$ 26,500
6. Land and Land Rights					135,000
Total Direct Cost					$ 804,000
Access Road					10,000
Contingencies, Engineering, and Administration					321,000
Total Project Cost					$1,135,000

REGIONAL PLAN

PENROSE RESERVOIR ON LITTLE RIVER

ESTIMATED COST

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Main Embankment and Saddle Dam					
Main Embankment					
Diversion and Care of Water		L.S.		$ 10,000	
Foundation Exploration and Treatment		L.S.		7,930	
Clearing and Grubbing	4	acre	300.00	1,200	
Earth Excavation and Stripping	13,908	cu. yd.	0.37	5,090	
Rock Excavation--Trench	2,420	cu. yd.	8.00	19,360	
Trench Concrete	451	cu. yd.	25.00	11,275	
Drain Tile and Blanket				14,215	
Rolled Fill	81,590	cu. yd.	0.45	36,715	
Stone Blanket	1,894	cu. yd.	3.00	5,680	
Riprap	6,322	cu. yd.	4.00	25,290	
Grassing and Sodding	8,460	sq. yd.	0.75	6,345	
Total Main Embankment				$143,100	
Saddle Dam					
Stripping and Earth Excavation	3,460	cu. yd.	0.43	1,495	
Rolled Fill	1,030	cu. yd.	1.00	1,030	
Quarry Fines	295	cu. yd.	3.00	885	
Dumped Rock	1,170	cu. yd.	4.00	4,680	
Grassing	260	sq. yd.	1.00	260	
Relocated Highway	1,200	lin. ft.	2.80	3,350	
Total Saddle Dam				11,700	
Total Main Embankment and Saddle Dam - - - - - - - - - - - - - - - -					$154,800
2. Spillway					
Foundation Exploration	Allowance			2,000	
Clearing and Grubbing	3	acre	300.00	900	
Stripping & Earth Excava.	15,580	cu. yd.	0.32	4,980	
Excavation--Rock	1,751	cu. yd.	3.50	6,130	
Backfill--Dumped Rock	140	cu. yd.	2.00	280	
Cleanup				500	
Concrete--Mass	560	cu. yd.	16.00	8,960	
--Paving	317	cu. yd.	18.00	5,705	
--Retaining Walls	366	cu. yd.	30.00	10,980	
--Core Wall	8	cu. yd.	33.00	265	
Total Spillway -					$ 40,700

REGIONAL PLAN

PENROSE RESERVOIR ON LITTLE RIVER

ESTIMATED COST
(Continued from the preceding cost)

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
3. Outlet Conduits and Intake Structures					
Outlet Conduits					
Foundation Preparation and Treatment	Allowance			$ 3,000	
Excavation--Earth	11,420	cu. yd.	0.30	3,430	
--Rock, Conduit	300	cu. yd.	5.50	1,650	
--Rock, Forebay	91	cu. yd.	5.00	455	
--Rock, Tailrace	716	cu. yd.	3.50	2,505	
Backfill--Earth	1,350	cu. yd.	0.50	675	
--Rock	2,206	cu. yd.	2.50	5,515	
Concrete--Barrel	1,150	cu. yd.	30.00	34,500	
--Walls	1,824	cu. yd.	25.00	45,525	
--Floor and Weir	206	cu. yd.	15.00	3,090	
Joints and Stops				755	
Total Outlet Conduits				101,100	
Intake Structures					
Foundation Exploration and Treatment		L.S.		1,200	
Excavation--Earth	653	cu. yd.	0.50	325	
--Rock	147	cu. yd.	4.00	590	
Backfill	163	cu. yd.	0.50	80	
Concrete--Mass	804	cu. yd.	20.00	16,080	
--Deck and Piers	147	cu. yd.	25.00	3,675	
--Reinforced (Tower)	96	cu. yd.	40.00	3,840	
Joints, Stops, Gates, Bridge and Electrical				45,110	
Total Intake Structures				70,900	
Total Outlet Conduits and Intake Structures					$172,000
4. Reservoir Adjustments (Houses)					28,000
5. Highway, Railroad, and Utility Relocation					--
6. Land and Land Rights					103,500
Total Direct Cost					$499,000
Access Road					25,000
Contingencies, Engineering, and Administration					201,000
Total Project Cost					$725,000

REGIONAL PLAN

CATHEYS RESERVOIR ON FRENCH BROAD RIVER

ESTIMATED COST

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Main Embankment					
Foundation Exploration and Treatment		L.S.		$ 13,000	
Diversion and Care of Water		L.S.		5,000	
Clearing and Grubbing		L.S.		600	
Excavation--Earth and Stripping	34,000	cu. yd.	0.33	11,400	
--Rock	3,150	cu. yd.	8.00	25,200	
Concrete Cut-off Wall	1,600	cu. yd.	20.00	32,000	
Trenching, Backfilling, and Filter				23,500	
Tile and Placing				1,300	
Rolled Earth Fill	263,200	cu. yd.	0.40	105,300	
Gravel	4,800	cu. yd.	2.00	9,600	
Rock Fill	17,250	cu. yd.	3.00	51,700	
Grassing	15,600	sq. yd.	0.75	11,700	
Total Main Embankment -					$290,300
2. Spillway					
Clearing, Grubbing, and Foundation, Clean-up		L.S.		8,645	
Stripping and Earth Excavation	23,400	cu. yd.	0.27	6,330	
Backfill--Earth	665	cu. yd.	0.60	400	
Rock Excavation	3,450	cu. yd.	2.00	6,900	
Concrete--Mass	3,600	cu. yd.	14.00	50,400	
--Paving	1,042	cu. yd.	15.00	15,640	
--Retaining Walls	1,489	cu. yd.	25.00	37,225	
--Core Wall	20	cu. yd.	33.00	660	
Joints and Stops				1,900	
Riprap	400	cu. yd.	4.00	1,600	
Total Spillway -					129,700

REGIONAL PLAN

CATHEYS RESERVOIR ON FRENCH BROAD RIVER

ESTIMATED COST
(Continued from the preceding page)

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
3. Outlet Conduits and Intake Structures					
Outlet Conduits					
Excavation--Earth	23,470	cu. yd.	0.30	$ 7,050	
--Rock (Conduit only)	500	cu. yd.	5.50	2,750	
Backfill (Conduit)	2,180	cu. yd.	0.50	1,090	
Foundation Preparation and Treatment		L.S.		3,200	
Concrete--Barrel	1,835	cu. yd.	30.00	55,000	
--Retaining Walls and Paving	1,642	cu. yd.	25.00	41,050	
--Floor and Weir	446	cu. yd.	15.00	6,700	
Excavation, Rock--Forebay and Tailrace	1,748	cu. yd.	3.50	6,130	
Backfill--Dumped Rock	1,130	cu. yd.	2.50	2,825	
Joints and Stops				975	
Total Outlet Conduits				126,770	
Intake Structures					
Exploration of Foundation and Treatment		L.S.		1,490	
Excavation--Earth	1,030	cu. yd.	0.50	515	
--Rock	147	cu. yd.	4.00	590	
Backfill	296	cu. yd.	0.50	145	
Concrete--Mass	984	cu. yd.	20.00	19,680	
--Piers and Deck	147	cu. yd.	25.00	3,680	
--Reinforced (Tower)	118	cu. yd.	40.00	4,720	
Joints and Stops, Gates, Electrical, Bridge, etc.				45,910	
Total Intake Structures				76,730	
Total Outlet Conduits and Intake Structures - - - - - - - - - - - - - -					$ 203,500
4. Reservoir Adjustments (Houses) - - - - - - - - - - - - - - - - - -					24,000
5. Highway, Railroad, and Utility Relocation					
Highway Relocation				16,000	
Railroad and Utility Relocation				--	
Total Highway, Railroad, and Utility Relocation - - - - - - - - - -					16,000
6. Land and Land Rights -					232,500
Total Direct Cost -					896,000
Access Road -					25,000
Contingencies, Engineering, and Administration - - - - - - - - - - -					354,000
Total Project Cost -					$1,275,000

REGIONAL PLAN

DAVIDSON RIVER RESERVOIR

ESTIMATED COST

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Main Embankment					
Foundation Exploration and Treatment		L.S.		$ 7,000	
Diversion and Care of Water		L.S.		20,400	
Excavation--Earth and Stripping	18,500	cu. yd.	0.40	7,400	
--Rock	2,700	cu. yd.	3.00	8,100	
--Rock Cut-off	363	cu. yd.	8.00	2,900	
Clearing and Grubbing	4	acre	300.00	1,200	
Trench Concrete	840	cu. yd.	20.00	16,800	
Permanent Drainage--Blanket of Tile				10,600	
Rolled Fill	114,200	cu. yd.	0.45	51,400	
Rock Fill--Quarry Fines and Small Rock	17,820	cu. yd.	3.00	53,400	
--Quarry Run Rock	51,860	cu. yd.	1.50	77,800	
Total Main Embankment -					$ 257,000
2. Spillway					
Foundation--Exploration and Treatment		L.S.		4,000	
Excavation--Earth	11,480	cu. yd.	0.30	3,440	
--Rock	20,600	cu. yd.	3.50	72,200	
Final Cleanup				1,000	
Concrete--Training and Cut-off Walls	1,110	cu. yd.	25.00	27,750	
Joints and Stops				610	
Total Spillway -					109,000

REGIONAL PLAN

DAVIDSON RIVER RESERVOIR

ESTIMATED COST
(Continued from the preceding page)

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
3. Outlet Conduits and Intake Structures					
Outlet Conduits					
Foundation Preparation and Treatment		L.S.		$ 2,250	
Excavation--Earth	15,070	cu. yd.	0.30	4,510	
--Rock (Conduit)	750	cu. yd.	5.50	4,130	
--Rock (Forebay and Tailrace)	1,624	cu. yd.	3.50	5,800	
Backfill--Earth	1,500	cu. yd.	0.50	750	
--Rock	1,000	cu. yd.	2.50	2,500	
Concrete--Barrel, Slab, etc.	1,200	cu. yd.	30.00	36,000	
--Wall & Pavements	1,040	cu. yd.	25.00	26,000	
--Floor & Weir	290	cu. yd.	15.00	4,350	
Joints and Stops, etc.				950	
Total Outlet Conduits				87,240	
Intake Structures					
Foundation Exploration and Treatment		L.S.		700	
Excavation--Earth	1,000	cu. yd.	0.50	500	
--Rock	300	cu. yd.	4.00	1,200	
Concrete--Mass	840	cu. yd.	20.00	16,800	
--Piers and Deck	153	cu. yd.	25.00	3,800	
--Reinforced (Tower)	444	cu. yd.	40.00	17,760	
Joints, Gates, Bridge, Electrical, etc.				47,000	
Total Intake Structures				87,760	
Total Outlet Conduits and Intake Structures - - - - - - - - - - - - -					$175,000
4. Reservoir Adjustments -					--
5. Highway, Railroad, and Utility Relocation					
Highway Relocation				22,000	
Railroad and Utility Relocation				--	
Total Highway, Railroad, and Utility Relocation - - - - - - - - - -					22,000
6. Land and Land Rights -					--
Total Direct Cost -					$563,000
Contingencies, Engineering, and Administration - - - - - - - - - - -					227,000
Total Project Cost -					$790,000

REGIONAL PLAN

MILLS RIVER RESERVOIR

ESTIMATED COST

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Main Embankment and Saddle Dam					
Main Embankment					
Foundation Exploration and Treatment		L.S.		$ 8,000	
Clearing and Grubbing	5	acre	300.00	1,500	
Stripping and Earth Excavation	26,900	cu. yd.	0.40	10,700	
Excavation--Rock	3,600	cu. yd.	3.00	10,800	
--Rock Cut-off Trench	550	cu. yd.	8.00	4,400	
Diversion and Care of Water		L.S.		10,000	
Trench Concrete	1,100	cu. yd.	20.00	22,000	
Drain Blanket and Tile				12,900	
Rolled Fill	153,000	cu. yd.	0.45	69,000	
Quarry Fines and Small Rock	24,230	cu. yd.	3.00	72,700	
Quarry Run Rock	75,400	cu. yd.	1.25	94,000	
Total Main Embankment				$316,000	
Saddle Dam					
Foundation Exploration		L.S.		1,100	
Stripping and Earth Excavation	9,200	cu. yd.	0.50	4,600	
Clearing and Grubbing	3	acre	300.00	900	
Rolled Fill	28,000	cu. yd.	0.60	16,800	
Stone Blanket and Dumped Rock	4,670	cu. yd.	3.00	14,000	
Grassing and Sodding	3,600	cu. yd.	1.00	3,600	
Total Saddle Dam				41,000	
Total Main Embankment and Saddle Dam - - - - - - - - - - - - - - - - - -					$357,000
2. Spillway					
Foundation Excavation and Treatment		L.S.		1,800	
Final Cleanup				540	
Stripping and Earth Excavation	11,615	cu. yd.	0.32	3,765	
Backfilling	390	cu. yd.	0.50	195	
Overflow--Concrete	2,085	cu. yd.	20.00	41,700	
Concrete Walls, Paving, and Cut-off	2,315	cu. yd.	25.00	57,900	
Steel Sheet Piling	6,700	sq. ft.	1.50	10,000	
Joints and Stops				1,000	
Gravel Blanket	533	cu. yd.	3.00	1,600	
Riprap	875	cu. yd.	4.00	3,500	
Total Spillway -					122,000

REGIONAL PLAN

MILLS RIVER RESERVOIR

ESTIMATED COST
(Continued from the preceding page)

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
3. Outlet Conduits and Intake Structures					
Outlet Conduits					
Excavation--Earth	16,540	cu. yd.	0.30	$ 4,970	
--Rock (Conduit)	2,015	cu. yd.	5.50	11,100	
--Rock (Forebay and Tailrace)	1,660	cu. yd.	3.50	5,800	
Foundation Preparation and Treatment	Allowance			2,000	
Concrete--Barrel	1,604	cu. yd.	30.00	48,100	
--Floor and Weir	290	cu. yd.	15.00	4,350	
--Walls and Paving	1,040	cu. yd.	25.00	26,000	
Joints and Stops				880	
Dumped Rock Backfill	1,000	cu. yd.	2.50	2,500	
Total Outlet Conduits				$105,700	
Intake Structures					
Foundation Exploration and Treatment		L.S.		600	
Excavation--Earth	1,000	cu. yd.	0.50	500	
--Rock	300	cu. yd.	4.00	1,200	
Concrete--Mass	840	cu. yd.	20.00	16,800	
--Piers and Deck	153	cu. yd.	25.00	3,800	
--Reinforced (Tower)	444	cu. yd.	40.00	17,760	
Joints, Stops, Gates, Bridge, and Electrical				49,640	
Total Intake Structures				90,300	
Total Outlet Conduits and Intake Structures - - - - - - - - - - - - - -					$ 196,000
4. Reservoir Adjustments -					22,000
5. Highway, Railroad, and Utility Relocation					
Highway Relocation				21,000	
Railroad and Utility Relocation				--	
Total Highway, Railroad, and Utility Relocation - - - - - - - - - - -					21,000
6. Land and Land Rights -					34,000
Total Direct Cost -					$ 752,000
Access Road and Camp -					50,000
Contingencies, Engineering, and Administration - - - - - - - - - - -					298,000
Total Project Cost -					$1,100,000

REGIONAL PLAN

LOCAL PROTECTION WORKS, FRENCH BROAD RIVER

ASHEVILLE, NORTH CAROLINA

ESTIMATED COST

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Levee					
Earth Embankment	250,000	cu. yd.	0.50	$125,000	
Concrete Wall	700	cu. yd.	30.00	21,000	
Steel Sheet Piling	92,500	lb.	0.06	5,600	$151,600
2. Street Adjustments					
Earth Fill and Grading	24,000	cu. yd.	0.50	12,000	
Paving--Concrete 20' wide	1,950	lin. ft.	6.00	11,700	
--Asphalt " "	1,100	lin. ft.	3.00	3,300	
--Gravel " "	4,000	lin. ft.	1.00	4,000	31,000
3. Interior Storm Water Drainage					
Pumping Plant for Town Creek		L.S.		105,000	
Concrete Pipe--60" diam.	700	lin. ft.	11.00	7,700	
--42" diam.	150	lin. ft.	6.00	900	
--36" diam.	800	lin. ft.	4.50	3,600	
--24" diam.	500	lin. ft.	3.00	1,500	
Excavation and Backfill	2,700	cu. yd.	2.00	5,400	
Automatic Sluice Gates--24" diam.	6	gate	75.00	500	124,600
4. Utilities					
Adjustments in Sewer and Water Lines and Pole Lines		L.S.			25,000
5. Right of Way for Levee and Borrow Pits					17,000
6. Relocation of Existing Buildings					15,000
Total Direct Cost					$364,200
Contingencies, Engineering, and Administration					145,800
Total Project Cost					$510,000

ASHEVILLE ONLY PLAN

BRITTON MOUNTAIN RESERVOIR ON FRENCH BROAD RIVER

ESTIMATED COST

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Main Dam Including Spillway and Conduits					
Foundation Exploration and Treatment		L.S.		$ 24,000	
Cofferdam No. 1, 20' Timber Crib	1,220	lin. ft.	60.00	73,200	
Cofferdam No. 2, 8' Earth Dike	2,500	lin. ft.	0.30	750	
Pumping and Maintenance		L.S.		10,000	
Clearing and Grubbing	5	acre	300.00	1,500	
Excavation--Earth	34,800	cu. yd.	0.50	17,400	
--Rock	7,340	cu. yd.	3.50	25,700	
Cleanup				2,450	
Concrete--Mass	55,100	cu. yd.	12.00	661,000	
--Walls, Apron, and Sill	3,650	cu. yd.	15.00	55,000	
Joints and Stops				12,000	$ 883,000
2. Reservoir Adjustments					84,000
3. Highway Relocation					---
4. Land and Land Rights					1,165,000
Total Direct Cost					2,132,000
Access Road					25,000
Contingencies, Engineering, and Administration					843,000
Total Project Cost					$3,000,000

ASHEVILLE ONLY PLAN

LOCAL PROTECTION WORKS, FRENCH BROAD RIVER

ASHEVILLE, NORTH CAROLINA

ESTIMATED COST

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Levee					
Earth Embankment	184,000	cu. yd.	0.50	$92,000	
Concrete Wall	520	cu. yd.	30.00	15,600	
Steel Sheet Piling	80,000	lb.	0.06	4,800	$112,400
2. Street Adjustments					
Earth Fill and Grading	19,000	cu. yd.	0.50	9,500	
Paving--Concrete 20' Wide	1,900	lin. ft.	6.00	11,400	
--Asphalt " "	1,100	lin. ft.	3.00	3,300	
--Gravel " "	4,000	lin. ft.	1.00	4,000	28,200
3. Interior Storm Water Drainage					
Town Creek Gravity Drain					
Concrete, Reinforced	1,400	cu. yd.	50.00	70,000	
Excavation and Backfill	1,000	cu. yd.	2.00	2,000	
				72,000	
Concrete Pipe - 60" Diam.	700	lin. ft.	11.00	7,700	
- 42" Diam.	150	lin. ft.	6.00	900	
- 36" Diam.	800	lin. ft.	4.50	3,600	
- 24" Diam.	400	lin. ft.	3.00	1,200	
Excavation and Backfill, Pipe Drains	2,600	cu. yd.	2.00	5,200	
Automatic Sluice Gates, 24" Diam.	6	gate	75.00	500	91,100
4. Utilities					
Adjustments in Sewer and Water Lines and Pole Lines		L.S.			25,000
5. Right of Way for Levee and Borrow Pits					15,000
6. Relocation of Existing Buildings					15,000
Total Direct Cost					$286,700
Contingencies, Engineering, and Administration					116,300
Total Project Cost					$403,000

LOCAL PROTECTION WORKS

MARSHALL, NORTH CAROLINA

ESTIMATED COST

A. PLAN FOR COMPLETE FLOOD PROTECTION

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Concrete Levee Wall					
Reinforced Concrete	15,000	cu. yd.	30.00	$450,000	
Excavation	7,000	cu. yd.	4.00	28,000	
Fill Behind Wall	20,000	cu. yd.	1.00	20,000	$498,000
2. Street and Railroad Openings					
Structural Steel	90	ton	300.00	27,000	
Hoists	6	hoist	2,000.00	12,000	39,000
3. Drainage					
Concrete Pipe--60" Diam.	400	lin. ft.	11.00	4,400	
Excavation and Backfill	1,000	cu. yd.	4.00	4,000	
Automatic Sluice Gates					
60" Diam.	4	gate	500.00	2,000	
24" Diam.	1	gate	125.00	125	
15" Diam.	1	gate	75.00	75	10,600
Total Direct Cost -					$547,600
Contingencies, Engineering, and Administration - - - - - - - - - - -					219,400
Total Project Cost -					$767,000

LOCAL PROTECTION WORKS

MARSHALL, NORTH CAROLINA

ESTIMATED COST

B. PLAN FOR PROTECTION EQUAL TO 1916 FLOOD

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Concrete Levee Wall					
Reinforced Concrete	10,000	cu. yd.	30.00	$300,000	
Excavation	4,400	cu. yd.	4.00	17,600	
Fill Behind Wall	17,000	cu. yd.	1.00	17,000	$334,600
2. Street and Railroad Openings					
Structural Steel	48	ton	300.00	14,400	
Hoists	6	hoist	1,500.00	9,000	23,400
3. Drainage					
Concrete Pipe--60" Diam.	400	lin. ft.	11.00	4,400	
Excavation and Backfill	1,000	cu. yd.	4.00	4,000	
Automatic Sluice Gates					
60" Diam.	4	gate	500.00	2,000	
24" Diam.	1	gate	125.00	125	
15" Diam.	1	gate	75.00	75	10,600
Total Direct Cost					$368,600
Contingencies, Engineering, and Administration					147,400
Total Project Cost					$516,000

LOCAL PROTECTION WORKS

MARSHALL, NORTH CAROLINA

ESTIMATED COST

C. PLAN FOR PROTECTION EQUAL TO 1940 FLOOD

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Concrete Levee Wall					
Reinforced Concrete	6,000	cu. yd.	30.00	$180,000	
Excavation	3,000	cu. yd.	4.00	12,000	
Fill Behind Wall	8,500	cu. yd.	1.00	8,500	$200,500
2. Street and Railroad Openings					
Structural Steel	1.75	ton	200.00	350	
Timber Stop Logs	6.5	m. ft.	100.00	650	1,000
3. Drainage					
Concrete Pipe--60" Diam.	400	lin. ft.	11.00	4,400	
Excavation and Backfill	1,000	cu. yd.	4.00	4,000	
Automatic Sluice Gates					
60" Diam.	4	gate	500.00	2,000	
24" Diam.	1	gate	125.00	125	
15" Diam.	1	gate	75.00	75	10,600

Total Direct Cost - $212,100
Contingencies, Engineering, and Administration - - - - - - - - - - - - 84,900

Total Project Cost - $297,000

LOCAL PROTECTION WORKS

PIGEON RIVER

CANTON, NORTH CAROLINA

ESTIMATED COST

A. PLAN FOR PROTECTION 10 FEET ABOVE 1940 FLOOD

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Earth Embankment for Levee	90,000	cu. yd.	0.40		$ 36,000
2. Concrete Wall (Mass Concrete)	1,200	cu. yd.	14.00		16,800
3. Railroad and Highway Openings (5)					
Reinforced Concrete	540	cu. yd.	25.00	$13,500	
Steel Sheet Piling	33,000	lb.	0.15	5,000	
Steel Gates & Guides (4)	11	ton	300.00	3,300	
Structural Steel Supports	4	ton	300.00	1,200	
Timber Stop Logs	1.0	m. ft.	100.00	100	
Hoists	4	hoist	1,500.00	6,000	29,100
4. Relocation of Existing Structures					
Commercial and Residential Buildings	16	bldgs.	1,000.00	16,000	
Pumping Station				3,000	
Railway Tracks				5,000	
Fibreville Road				2,000	26,000
5. Drainage Outlets Under Levee					10,000
6. Land for Right of Way and Borrow Pits					5,000

Total Direct Cost - $122,900
Contingencies, Engineering, Administration - - - - - - - - - - - - - - 49,100

Total Project Cost - $172,000

LOCAL PROTECTION WORKS

PIGEON RIVER

CANTON, NORTH CAROLINA

ESTIMATED COST

B. PLAN FOR PROTECTION 5 FEET ABOVE 1940 FLOOD

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Earth Embankment for Levee	50,000	cu. yd.	0.40		$ 20,000
2. Concrete Wall (Mass Concrete)	440	cu. yd.	14.00		6,200
3. Railroad and Highway Openings (5)					
Reinforced Concrete	200	cu. yd.	25.00	$ 5,000	
Steel Sheet Piling	15,400	lb.	0.15	2,300	
Timber Stop Logs	5	m. ft.	100.00	500	7,800
4. Relocation of Existing Structures					
Commercial and Residential Buildings	14	bldgs.	1,000.00	14,000	
Pumping Station				3,000	
Railway Tracks				5,000	
Fibreville Road				2,000	24,000
5. Drainage Outlets Under Levee					10,000
6. Land for Right of Way and Borrow Pits					4,000

Total Direct Cost - $ 72,000
Contingencies, Engineering, Administration - - - - - - - - - - - - - - - - 29,000

Total Project Cost - 101,000

LOCAL PROTECTION WORKS

HOMINY CREEK

NEAR ENKA, NORTH CAROLINA

ESTIMATED COST

Feature	Quantity	Unit of Quantity	Unit Price	Amount	Total
1. Earth Embankment for Levee	160,000	cu. yd.	0.25		$ 40,000
2. Concrete Wall at Filter Plant (Mass Concrete)	800	cu. yd.	14.00		11,200
3. Railroad and Highway Openings (2)					
Reinforced Concrete	550	cu. yd.	25.00	$ 13,800	
Steel Sheet Piling	1,200	sq. ft.	2.00	2,400	
Steel Gates and Guides	12	ton	300.00	3,600	
Structural Steel Supports	3	ton	300.00	900	
Hoists	2	hoist	2,000.00	4,000	24,700
4. Relocation of Pump House					2,000
5. Sluiceway					
Reinforced Concrete	70	cu. yd.	25.00	1,800	
Excavation and Backfill	150	cu. yd.	2.00	300	
Automatic Sluice Gate, 3 ft. x 3 ft.	1	gate	300.00	300	2,400
6. Land for Right of Way and Borrow Pits					1,000
Total Direct Cost					$ 81,300
Contingencies, Engineering, and Administration					32,700
Total Project Cost					$114,000

Tennessee Valley Authority
Water Control Planning Department
Hydraulic Data Division

APPENDIX F

INFLUENCE OF IMPROVED LAND USE

ON

FLOOD CONTROL AND TOTAL WATER CONSERVATION

UPPER FRENCH BROAD WATERSHED

Knoxville, Tennessee
August 1942

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APPENDIX F

INFLUENCE OF IMPROVED LAND USE

ON

FLOOD CONTROL AND TOTAL WATER CONSERVATION

UPPER FRENCH BROAD WATERSHED

The Activity Authorization for the Upper French Broad Valley flood protection investigations states "that consideration will be given to the protection and conservation of agricultural lands and to the possibilities of further alleviation of flood damage through the protection and improvement of the watershed through better land use. The cooperation of state and local agencies will be sought where appropriate in the conduct of this study." Studies of this kind have been made jointly by the North Carolina State College Extension Service and the Tennessee Valley Authority. The State College has in preparation a report "Land Cover and Its Relationship to the Control and Utilization of Water in the Upper French Broad River Watershed, North Carolina." That report, prepared by Mr. William D. Lee, Extension Soil Specialist, discusses the agricultural phases of the problem and contains much information and data necessary to a full comprehension of the part that land use has in water control and utilization. The hydrologic or engineering aspects of the influence of improved land use practices and management on flood control and total water conservation have been summarized in a preceding section of this report and will be described in more detail in this Appendix.

Methods

In studying the influence that land use and cover have on flood and surface runoff, the general procedure has been as follows:

1. A classification of lands was adopted which was applicable to the entire watershed.

2. The watershed was subdivided into sub-watersheds of suitable size for hydrologic analysis.

3. All lands in each sub-watershed were classified according to present land use on the basis of the adopted classification system.

4. Present land use in each sub-watershed was correlated by hydrologic methods with rainfall and runoff for past floods such as those of August 1940 and April 1936.

5. Plans were developed for improving vegetal cover through better land use and management over a 20-year future period.

6. The effect of these planned improvements was evaluated for each sub-watershed and each important location such as Asheville with respect to decreases in surface runoff and flood heights for the floods of August 1940 and July 1916.

Land Classification and Surveys

Land Use Classes

Prior to initiating field classification of lands, conferences were held between the hydrologists, agriculturists, and foresters and a uniform classification was worked out into which it was considered that all of the lands in the Upper French Broad region could be classified particularly with regard to their capacity for infiltration of surface water into the soil. This provided a basis for a common understanding of each land class by the various persons engaged on the field surveys. Infiltration data was available from the Bent Creek watershed of the Appalachian Forest Experiment Station and the classification system was set up to correspond to the land classes of the experimental watersheds in order that the data from these could be used.

TABLE 1

LAND USE CLASSIFICATION

A. Forest

F_1 - Canopy, (including understory), 80% or more.
Litter - 3 inches minimum depth. Should cover at least 90% of ground surface.
A_1 Horizon of soil - 4 inches minimum depth of organic layer, and partly decomposed litter.
Soil - 2 feet minimum depth.
Slope - No limitation.
Exposure - Generally north, east, or northwest.
Fire damage - None in recent years.
Grazing - None.

F_{2+} - Canopy, (including understory), 60 to 80%.
Litter - 2-3 inches minimum depth. Should cover not less than 90% of ground surface.
A_1 Horizon of soil - 2 inches minimum depth of organic layer and partly decomposed litter.
Soil - 1½-2 feet minimum depth.
Slope - No limitation.
Exposure - Generally north, east, or northwest.
Fire damage - None in recent years.
Grazing - None.

F_2 - Canopy, (including understory) 25 to 60%.
Litter - 1-2 inches in depth and covering at least 80% of ground surface.
A_1 Horizon of soil - Organic matter 1-2 inches in depth.
Soil - 1-1½ feet in depth.
Slope - No limitation.
Exposure - No limitation.
Fire damage - None in recent years.
Grazing - None.

F_3 - Canopy, (including understory), 25% or less.
Litter - Generally very thin. Coverage less than 75% of ground surface.
A_1 Horizon of soil - less than 1 inch depth of organic layer.
Soil - Not more than 12 inches in depth.
Slope - No limitation.
Exposure - No limitation.
Fire damage - Often, or recently burned.
Grazing - Generally grazed.

B. Pasture

P_1 - Coverage - Complete, no bare spots, grass $1\frac{1}{2}$ inches minimum height.
Grazing - Apparently not over-grazed.
Trampling - Apparently not trampled sufficiently to cut sod.
Soil - Usually deep - 2 feet minimum, and of the "better" series as Porters, Clifton, Balfour.
Slope - Related to soil association but in general not over 50%. Hayesville or Halewood P_1 slope range less than Porters.
Erosion - No active erosion.

[A P_1 pasture should show evidence of good management. It may be terraced, contour furrowed, and used in rotation with other pastured for controlled grazing. Weeds are clipped. A very heavy broomsedge sod is P_1. There is very little P_1 pasture in the area.]

P_{2+} - Coverage - Complete, no bare spots, grass 1 inch minimum height.
Grazing - Not over-grazed.
Trampling - No excessive trampling.
Soil - Generally 2 feet minimum depth, and on such series as Porters, Balfour, and Congaree.
Slope - Related to soil association.
Erosion - No active erosion.

[This is "top grade" of pasture usually found in French Broad Valley area.]

P_2 - Intermediate between P_{2+} and P_3. Some of the steeper P_{2+} areas should come in this group, especially on Halewood, Hayesville and similar soil associations.

[Most lespedeza pasture is P_2.]

P_3 - Coverage - Generally less than 60%. Usually has bare spots.
Grazing - Apparently over-grazed.
Trampling - Usually severely trampled.
Soil - General soil factors are dependent upon other conditions. ("Good" soils may be severely eroded because of poor management, etc.)
Slope - Rather important, and a contributing factor to erosion.
Erosion - Usually quite active. Often severe gully damage.

[Grazed woodlands classed as pasture are P_3. A P_3 pasture shows little evidence of management.]

C. Cultivated Land

C_1 - Coverage - Generally close-growing vegetation on uplands, may be row crops on bottomlands and colluvial areas. Growth vigorous.
Slope - Generally less than 20%.
Soils - Favorable (well-drained alluvial soils, terrace soils, colluvial soils; also Balfour, Hayesville.)
Erosion - Apparently there has been only slight to moderate erosion loss, but none active at present.
Management - Consider breaking (contour or other), tillage (contour or not), terracing, rotation system, etc. Growth of crops is an indication of fertility and also of infiltration.

/Highest rate of infiltration is on C_1 land, which means minimum erosion and favorable soil conditions./

C_2 - Intermediate between C_1 and C_3. (Slope largely between 20% and 40%.)

C_3 - Coverage - Generally row crops, poor.
Slope - Usually above 10%.
Soils - Largely Halewood, Hayesville, Fletcher.
Erosion - Moderately severe to severe, and active.
Management - Area shows every indication of poor handling such as rows down slope.

D. Rock

This includes areas whose surface is almost entirely rock outcrops.

E. Idle Land

This includes cropland "resting" or not in crop this or past season, but not yet in trees. Land to be placed in C_1, C_2, or C_3 group according to slope, soil association, and erosion conditions.

F. Waste Land

This includes land abandoned because too steep, too eroded, or for other reasons. If pastured place with P_3; if not pastured place with F_3.

G. Hay Crop Areas

These should be placed with C classes, according to cover, permanence, slope, etc. Most hay meadows are C_1. Annual lespedeza is C_2. Some hay areas on steep slopes are C_2 on such soil associations as Halewood and Ashe.

The classification as adopted with some slight modifications is given in the accompanying table 1. This places all lands primarily into three main groups, Forest, Pasture, or Cultivated. Each of these groups was subdivided into three or four classes, from good to poor, based on recognizable qualities of soil and cover. A fourth group, rock, was added during the field surveys to designate areas whose surface is almost entirely rock outcrops. This classification was used throughout the study both in surveys of present land use and in estimates of future land use.

Watershed Subdivisions

For purposes of the investigation, the French Broad Basin above Marshall was divided into 15 sub-areas and the Pigeon River watershed above Canton was divided into two sub-areas. Those are shown on plate 41 in the body of the report. Wherever possible, these unit areas were laid out so that there was a stream gaging station at the downstream end of the area. In a few cases this was not possible.

Strip Surveys

The North Carolina State College Extension Service made a determination of land use in each sub-watershed area by means of strip surveys which were adopted as a satisfactory means of sampling the whole basin above Marshall. According to Extension Soil Specialist William D. Lee in charge of the work "each strip survey was made by completely covering all the land in an area one-half mile wide and which reached completely across an individual valley -- from ridge crest to ridge crest. In this manner all variations of topography were encountered, together with the full scope of land use and character of cover. There are ten such strips, each carefully selected with the aid of the county farm agent so that it would be as representative as possible of the individual drainage basin. These strips are located near Quebec and at Cherryfield in Transylvania County; at Etowah and near Dana in Henderson County; near Fairview, at Candler, and above Weaverville in Buncombe County; close to Mars Hill and near California in Madison County; and near Retreat in Haywood County. The acreage in the various strips ranges from about 1000 to over 5000. The determination of row crops, small grain, hay; of soil, slope, and erosion, and so on, was as accurate as possible. With these data the information for each cover class (C_1, C_2, P_1, F_1, etc.) was 'blown up' - by carefully weighing actual cover, soil association, and erosion conditions - to cover the individual drainage areas as shown on the basin map. Thus a complete picture of the whole French Broad area was obtained."

Forest Surveys

The Forestry Relations Department measured the total acreage of open and forested land in each sub-watershed and also made field surveys to classify forest lands into one of the four forest classes or as rock. The strip survey method was not considered applicable to the forest lands and the entire area of forested lands was gone over in the field and classified by trained foresters.

Director Willis M. Baker, Forestry Relations Department, describes the forest surveys as follows: "The mapping of these infiltration classes

was carried out by technical foresters, who examined the entire forest area and indicated the various classes to 10-acre minimum units on planimetric maps showing forest cover. Simultaneously, predictions were made of the length of time needed under proper management for the areas to advance from the present class to the next higher class. Since these predictions were based on the assumption that recommended measures for improvement would be completely carried out, and since this assumption is improbable, other tables were prepared showing the changes which might reasonably be expected should such a program be inaugurated. These rates of change were then carefully checked with the Appalachian Forest Experiment Station and the North Carolina Agricultural Extension Service."

Infiltration

One of the most important elements in the evaluation of the effect of land and land use on storm runoff is the capacity of the land to absorb or infiltrate rainfall. The rate at which soil in any one place with a definite cover can absorb rain varies depending on conditions prior to a rain, the intensity of rain and the duration of rain. The potential infiltration rate at any time during the storm is the maximum rate at which the soil in its then condition can absorb rain. This rate is the highest at the beginning of a storm and decreases, becoming more nearly constant as the duration of the storm lengthens. For the purpose of this investigation, the term "infiltration rate" refers to the average rate of infiltration which is derived by considering an entire storm as a unit. This rate is computed by determining the rate at which the volume of rainfall occurring at higher intensities is just equal to the volume of surface runoff. Although actually infiltration rate varies throughout a storm, the use of the average rate in this study is justified because the length of storms studied is sufficient so that the average rate may be used without serious error.

Infiltration rates vary with land use, soil series, season, initial soil moisture conditions, amount and intensity of rain, the length of the unit time period used to compute rainfall intensities, and to a lesser extent with other factors. Assuming that soil types are sufficiently similar to give comparable results and considering only large storms, and using half-hour periods for computing rainfall intensity in all cases, specific values for average infiltration rates referred to land use and season were established. While the assumptions are not absolutely correct, conditions within the watershed are such that the conclusions reached with regard to trends are accurate although finite values of flood height reductions are subject to the limitations of the available data.

Experimental Infiltration Rates

Bent Creek Experimental Area--Data collected at the Appalachian Forest Experiment Station at Bent Creek near Asheville largely formed the basis for the determination of theoretical infiltration rates. On the Bent Creek area rainfall amounts and intensity and streamflow have been measured for areas varying in size from 10 to 735 acres. Over the period of record of collection of data from these areas, rainfall and runoff have been obtained on the following classes of land use: F_1, F_2, P_2, P_3, and C_2.

Blacksburg Experimental Area--Two experimental watersheds are operated by the Virginia Agricultural Experiment Station near Blacksburg, Virginia. These are located on the Virginia Polytechnic Institute Farm. The watershed selected for detailed study is 5.44 acres in area, has prevailing land slopes from six to ten percent, and has one principal waterway which is 600 feet long. The entire area is in cultivation and is cropped to corn, wheat, and clover in a 3-year rotation. Four major storms occurring under three types of land use were considered from data at this station. The results of this analysis were valuable in that they furnished data in the C_3, C_1, and P_2 to P_{2+} classes of land uses which were not available at Bent Creek.

Analysis of Experimental Data--The analysis of Bent Creek and Blacksburg data were treated together since the data and the method of analysis were in every way similar. Rainfall data were available in the form which indicates rainfall intensities for periods to the nearest minute. The runoff records used were prepared in a similar manner.

Approximately sixty storms, some of which occurred on more than one area, were studied to develop the winter and summer experimental infiltration rates for the eleven types of land use available. It was found that the most consistent results were obtained when the rainfall pattern was reduced to half-hour intensities for analysis. The infiltration rate was computed by trial and error, solving for that position such that the volume of rainfall occurring at intensities higher than this rate would be equal to the volume of surface runoff which amounts were determined by a separation of the experimental hydrograph tabulations.

The individual computed storm infiltration rates were averaged within each classification by seasons to give the final experimental infiltration rates. These are shown in table 2 "Land Use Infiltration Rates." The rates for the F_{2+}, F_3, and P_1 classes were based largely on an extrapolation of the known data.

Experimental Infiltration Rates Applied to Unit Areas

The experimentally derived infiltration rates were used to obtain theoretical infiltration rates for selected unit areas in the French Broad watershed. These areas were selected for check purposes because stream flow for the areas had been measured at regular gaging stations and because they represent a wide range of land use. The areas are the French Broad at Rosman, the Davidson at Brevard, the Mills River at Mills River, the Mud Creek at Naples, the Swannanoa at Biltmore, and the Pigeon at Canton. The experimental infiltration rates for the eleven classes were weighted in the proportion that each land class existed as determined for present conditions in the land use surveys. Since the experimental infiltration rates are different for the winter and summer seasons, two sets of theoretical areal infiltration rates were computed. The theoretical areal infiltration rates are shown in table 3, "Comparison of Areal Infiltration Rates."

Observed Infiltration Rates on Unit Areas

The floods of April 1936 are considered typical of the winter season and the floods of August 1940 typical of the summer season. The

TABLE 2

LAND USE INFILTRATION RATES

Inches per Hour

	Summer		Winter	
Class	Experimental Infiltration Rate	Revised Infiltration Rate	Experimental Infiltration Rate	Revised Infiltration Rate
C_1	.70	.56	.26	.21
C_2	.40	.32	.18	.14
C_3	.23	.18	.15	.12
P_1	.70	.56	.30	.24
P_{2+}	.55	.44	.27	.22
P_2	.45	.36	.25	.20
P_3	.27	.22	.17	.14
F_1	.75	.60	.29	.23
F_{2+}	.65	.52	.26	.21
F_2	.51	.41	.24	.19
F_3	.30	.24	.17	.14

TABLE 3

COMPARISON OF AREAL INFILTRATION RATES

Inches per Hour

		Summer			Winter		
Sub-Watershed		Observed	Infiltration Rates		Observed	Infiltration Rates	
Number	Name	(1940)	Theoretical	Revised	(1936)	Theoretical	Revised
1	Rosman	.43	.47	.38	-	-	-
4	Davidson	.40	.46	.37	.18	.22	.18
5	Mills	.35	.48	.38	.16	.22	.18
7	Mud	.25	.44	.35	-	-	-
12	Swannanoa	.30	.44	.35	.17	.21	.17
22-23	Pigeon	.31	.42	.33	.15	.21	.17

rainfall and runoff records for these storms were analyzed on the six unit areas to determine the observed areal infiltration rates. The method used was identical in principle with that employed for the Bent Creek and Blacksburg experimental records. The procedure was to compute the average rainfall for each area and use a pattern corresponding to the nearest recording rain gage. The runoff was determined from analysis of the hydrographs obtained from hourly stream flows. The observed areal rates corresponding to winter and summer are shown in table 3.

Comparison of Theoretical and Observed Infiltration Rates

The theoretical and observed infiltration rates computed for the selected unit areas were in reasonably good agreement, although the former were slightly higher than the observed for both summer and winter. After consideration of the data and watershed conditions, the experimental infiltration rates shown in table 2 were reduced by 20 percent to the amounts indicated under the head "Revised Infiltration Rate." The latter rates were those used in the hydrologic studies.

Hydrologic Data and Determinations

In addition to infiltration rates for the several land classes, rainfall and stream flow data are required for hydrologic analyses.

Rainfall

In the Upper French Broad region, rainfall records for the 1940 storms are available from daily and recording gages and from supplemental observations. Somewhat less complete data are available for the April 1936 storms. For earlier years, including July 1916, the actual recorded rainfall data is not adequate for purposes of hydrologic studies and has had to be supplemented by estimates of probable rainfall over the various parts of the watershed.

Stream Flow

In dividing the entire drainage basin into sub-watersheds, the downstream boundary was made wherever possible at a stream gaging station which was in operation during the 1940 floods. There are stations at the downstream boundary of each of the sub-watersheds, excepting Cane Creek, Hominy Creek, Swannanoa River at Bull Creek, and Sandymush Creek. For these four areas it has been necessary to estimate the flood hydrographs from the best available data.

Ground Water

The total flow in a stream is made up of surface runoff and ground water runoff. In studies of land use as related to stream flow, it is necessary to separate the ground water from the surface water runoff. After a rainless period sufficient in length to allow the runoff of all surface water to have taken place, the water then flowing in a stream comes from ground water sources. As time continues, the flow decreases in amount and these data furnish a basis for the development of ground water recession

curves. Such curves were developed for the French Broad River at Rosman, Blantyre, Bent Creek, and Asheville, and for the tributaries Davidson River near Brevard, Mud Creek at Naples, Mills River near Mills River, Swannanoa River at Biltmore, Ivy River near Marshall, and Pigeon River near Canton. For other French Broad tributaries, an average recession curve derived from the curves for the other streams was used.

Based on the ground water recession curves ground water volume curves were prepared so that the number of inches of water in storage in the ground at any time could be estimated.

River Reaches

In order to analyze stream flow on the French Broad River, the stream was divided into four reaches, one above Blantyre, from Blantyre to Bent Creek, from Bent Creek to Asheville, and from Asheville to Marshall. This divides the river into four approximately equal reaches at points where stream flow records are available for the August 1940 floods and also includes Asheville and Marshall which are points at which determinations of effects of land use on stream flow are desired.

Basic Assumptions

Summing up the factors which enter into the hydrologic studies of land use effects in the Upper French Broad watershed and the data which are available for these studies, the following basic assumptions were made.

1. Land in the watershed can be classified from an infiltration standpoint by physical characteristics of land use, soil series, and depth of soil.

2. Infiltration rates derived from small watersheds at Bent Creek and Blacksburg can be adjusted to be applicable to the area.

3. Eleven infiltration classes are sufficient to define the various land uses.

4. Experimental infiltration rates for eight types of land use can be extrapolated by judgment to cover the eleven classes.

5. The average infiltration rate method is satisfactory if only major storms are considered.

6. Thirty minutes is a reasonable period to use for computing rainfall intensity.

7. The April 1936 storms are typical of the winter-spring season and the August 1940 storms are typical of the summer-fall season.

8. From comparison of the theoretical and observed areal infiltration rates, the individual land class infiltration rates which are derived from Bent Creek and Blacksburg data should be reduced 20 percent.

9. Rainfall excess periods can be associated with subdivisions of the surface runoff hydrograph. In a few storms where the subdivisions of excess and runoff differ in volume, the infiltration rate may be varied slightly during the storm to obtain agreement. The estimated hydrographs for various projected land uses may be developed by reducing each subdivision of runoff by the actual change in the corresponding excess.

10. The character of the watershed is such that there is sufficient storage capacity to hold the additional water infiltrated as a result of improved cover.

Methodology for Determination of Land Use Effects

As a basis for calculations to determine the influence of improved land use on stream flow, the river system was checked through using the known rainfall and stream flow for a past storm. In this case the mid-August 1940 storm was used. In doing this, storage curves for the reaches of river considered were developed which were essential to later calculations. These determinations were checked by similar review of the late August flood preceding downstream and comparing results with the actual observed flood hydrographs. This procedure gave a hydrograph of flow at the lower end of each reach separated into surface runoff and ground water runoff for each flood.

In estimating the effect of improved land use, calculations were made in which the surface runoff was reduced in proportion to the changes to be brought about in land use. These changes also increase the ground water runoff. This procedure results in a net determination of the effect of the improved land use for each of the sub-watersheds and also at the ends of the four main river reaches. In the latter case, the reduced hydrograph at Blantyre was first developed and this, taken in conjunction with the reduced flow on the areas between Blantyre and Bent Creek, gave a reduced hydrograph at Bent Creek. This method was continued downstream for both Asheville and Marshall.

Improvements Of Unit Test Demonstration Farms

A study of 100 Unit Test Demonstration Farms in the French Broad area was made by the North Carolina State College Extension Service under the direction of Mr. William D. Lee, Extension Soil Conservationist. This study included a determination of the changes in land use and character of cover on the unit test demonstration farms in each of the subdivisions of the French Broad Basin. According to Mr. Lee, the farms were selected because of having complete records covering the 5-year period from 1935 to 1941. It so happened that the farms for which these records were available were scattered throughout the basin so that a good distribution of farms over the total drainage area resulted. The only missing area is that of the Swannanoa where there were no 5-year farm records.

Tabulations showing changes in land classes for the Unit Farms in each of the sub-watershed areas were furnished to the engineers by Mr. Lee.

TABLE 4

CHANGES IN INFILTRATION RATES

UNIT TEST DEMONSTRATION FARMS

UPPER FRENCH BROAD WATERSHED

1935 to 1941

Sub-Watershed Number	Sub-Watershed Name	Average Infiltration Rates (Inches Per Hour) Growing Season 1935	1941	Per Cent Change	Dormant Season 1935	1941	Per Cent Change
1	Rosman	.39	.41	5	.18	.18	0
2	French Broad--Rosman to Blantyre	.36	.43	19	.17	.19	12
3	Little River	.33	.42	27	.16	.19	19
5	Mills	.39	.41	5	.18	.19	6
6	French Broad--Blantyre to Bent Cr.	.31	.36	16	.16	.17	6
7	Mud	.39	.42	8	.18	.19	6
8	Cane	.34	.39	15	.17	.18	6
9	Lower Hominy	.30	.35	17	.15	.17	13
10	Upper Hominy	.25	.33	32	.14	.17	21
11	French Broad--Asheville to Marshall	.27	.34	26	.15	.17	13
13	Ivy	.27	.33	22	.15	.17	13
16	Sandymush	.29	.34	17	.15	.17	13
22	Pigeon--West Fork	.28	.37	32	.15	.18	20
23	Pigeon--East Fork	.34	.40	18	.17	.19	12

TABLE 5

EFFECT ON SURFACE RUNOFF

LAND USE IMPROVEMENT ON UNIT TEST DEMONSTRATION FARMS

GROWING SEASON

M = Flood of Mid-August 1940 L = Flood of Late August 1940

Sub-Watershed No.	Name	Flood	Ave. Rain	Average Infiltration Rates 1935	1941	Surface Runoff 1935	1941	Surface Runoff Reduction	
			Inches	Inches per Hr.		Inches		Inches	Percent
1	Rosman	M	11.21	.39	.41	1.48	1.34	.14	9
		L	9.24			3.54	3.39	.15	4
2	French Broad (Rosman to Blantyre)	M	11.07	.36	.43	1.70	1.21	.49	29
		L	7.63			2.70	2.26	.44	16
3	Little River	M	12.42	.33	.42	2.60	1.74	.86	33
		L	8.06			3.16	2.53	.63	20
5	Mills	M	11.46	.39	.41	1.58	1.42	.16	10
		L	8.48			3.01	2.88	.13	4
6	French Broad (Blantyre to Bent Creek)	M	7.00	.31	.36	.56	.38	.18	32
		L	6.99			2.64	2.30	.34	13
7	Mud	M	8.78	.39	.42	.66	.54	.12	18
		L	6.79			1.92	1.74	.18	9
8	Cane	M	5.20	.34	.39	.66	.50	.16	24
		L	6.37			1.48	1.22	.26	18
9	Lower Hominy	M	6.08	.30	.35	.90	.70	.20	22
		L	7.78			2.63	2.26	.37	14
10	Upper Hominy	M	7.10	.25	.33	.92	.48	.44	48
		L	7.70			3.73	2.92	.81	22
11	French Broad (Asheville to Marshall)	M	4.52	.27	.34	.49	.34	.15	31
		L	6.99			2.38	1.85	.53	22
13	Ivy	M	5.20	.27	.33	.72	.52	.20	28
		L	4.92			1.20	.90	.30	25
16	Sandymush	M	4.85	.29	.34	.52	.42	.10	19
		L	7.50			3.06	2.50	.56	18
22	Pigeon-West Fork	M	12.25	.28	.37	3.06	1.90	1.16	38
		L	9.99			4.86	3.94	.92	19
23	Pigeon-East Fork	M	10.88	.34	.40	1.76	1.28	.48	27
		L	8.43			3.39	2.94	.45	13

These reflect the changes in land use and character of cover. Complete data on the changes which have taken place on the Unit Test Demonstration Farms are contained in the report of the North Carolina State College previously mentioned.

The changes in infiltration rates which have occurred on the Unit Test Demonstration Farms for the 5-year period for the various areas into which the watershed has been subdivided are given in table 4 for the growing and dormant seasons. The effect of the changes in infiltration rates on runoff is shown in table 5 for the two August 1940 storms and in table 6 for the April 1936 storm. These tables show the rainfall during each storm which is estimated to have fallen on the farms in each sub-watershed and the resulting surface runoff as of 1935 and 1941. The reduction in surface runoff in inches of water and percent for each flood is shown. As has been previously pointed out, these figures should be considered as trends and not as absolute values.

TABLE 6

EFFECT ON SURFACE RUNOFF

LAND USE IMPROVEMENT ON UNIT TEST DEMONSTRATION FARMS

DORMANT SEASON*

Sub-Watershed No.	Name	Ave. Rain	Average Infiltration Rates 1935	1941	Surface Runoff 1935	1941	Surface Runoff Reduction	
		Inches	Inches per Hr.		Inches		Inches	Percent
1	Rosman	4.36	.18	.18	1.04	1.04	.00	0
2	French Broad (Rosman-Blantyre)	4.83	.17	.19	1.39	1.20	.19	14
3	Little River	5.97	.16	.19	2.24	1.90	.34	15
5	Mills	2.75	.18	.19	.32	.29	.03	9
6	French Broad (Blantyre-Bent Creek)	3.21	.16	.17	.60	.54	.06	10
7	Mud	3.71	.18	.19	.71	.66	.05	7
8	Cane	2.81	.17	.18	.38	.34	.04	11
9	Lower Hominy	1.69	.15	.17	.30	.26	.04	13
10	Upper Hominy	2.03	.14	.17	.49	.38	.11	22
11	French Broad (Asheville-Marshall)	1.74	.15	.17	.32	.28	.04	12
13	Ivy	1.84	.15	.17	.36	.31	.05	14
16	Sandymush	1.99	.15	.17	.42	.36	.06	14
22	Pigeon - West Fork	2.68	.15	.18	.42	.30	.12	29
23	Pigeon - East Fork	2.08	.17	.19	.16	.14	.02	12

* Storm of April 5, 1936 taken as typical.

Improved Land Use Programs

The North Carolina State College Extension Service and the Forestry Relations Department of the Authority developed programs for land use improvement for periods of 5, 10, 15, and 20 years in the future for the open lands and forest lands respectively.

Two programs were made, the conditions for which were formulated by the North Carolina State College. One, referred to in this report as the "possible program," is based on a maximum improvement of agricultural land use practices including extensive aid from Government agencies, use of fertilizer, good farming methods, and a high degree of cooperation from farmers in the area. The second, referred to as the "probable program," assumes a less intense development and one which might be expected to be accomplished practically.

The projection of land use on open lands was made by the North Carolina State College Extension Service and forest land changes were estimated by the Tennessee Valley Authority Forestry Relations Department. Interchange of forest and open land was discussed in conference and agreed upon by representatives of these agencies. The data from these programs were furnished to the engineers and are used for the determinations in this report of the effects of such changes upon the floods of August 1940 and that of July 1916. The Forestry Relations Department also prepared a program showing the changes in forest cover for a 60-year period.

Table 7, prepared by the North Carolina State College Extension Service, shows the projected land use programs by land cover classes for the combined sub-watershed areas.

As a concrete measure of what might be accomplished by land use changes, the two August 1940 and the July 1916 floods have been analyzed by hydrologic studies to determine the benefits in flood height reduction that could have been accomplished by each program during each of those floods. The results of these studies are given in the succeeding two sections of this report.

Although the land use programs were made for periods of 5, 10, 15, and 20 years, hydrologic studies were made only for the 20-year improvement period. The work involved in determining the effect of land use changes on stream flow hydrographs is considerable and after evaluating the effect of the 20-year changes, it was apparent that changes for intermediate periods may be approximated sufficiently close for practical purposes without making detailed calculations.

Floods of August 1940

The two floods in August 1940 are the fourth and fifth largest of record on the Upper French Broad River. Comparisons of the peak discharges for this flood with those occurring in 1916 at various stations are given in the section of this Appendix relating to the 1916 flood. A study of the two 1940 floods is of special value because of the amount of rainfall and stream flow data available.

TABLE 7

PROJECTED LAND USE PROGRAMS

Prepared by North Carolina State College Extension Service

A = Possible Program which assumes aid to all farmers similar to that received by Unit Test Demonstration Farms. Farmer participation expected, 40% in 1946, 60% in 1956, and 80% maximum in 1961.

B = Probable Program which is based on general aid to farms similar to 1941 conditions. Farmer participation expected, 30% in 1946, 50% in 1956, and 60% in 1961.

Forest programs by Forestry Relations Department, TVA. Figures shown are in Acres.

Cover Class	1941	1946 A	1946 B	1951 A	1951 B	1956 A	1956 B	1961 A	1961 B
C_1	64,131	75,468	69,190	86,901	78,620	106,913	85,850	119,491	88,000
C_2	74,469	69,250	68,920	59,785	62,890	34,590	53,457	22,012	50,312
C_3	72,266	53,457	66,284	47,168	56,600	44,000	54,508	37,820	50,358
P_1	4,028	6,289	5,345	9,433	6,200	12,578	7,861	15,725	9,400
P_{2+}	16,150	22,012	19,810	50,312	31,445	56,523	44,023	69,000	50,300
P_2	44,197	59,746	50,312	45,187	45,400	44,123	37,954	34,650	40,925
P_3	39,210	28,229	34,590	15,665	33,296	15,723	30,798	15,753	25,156
F_1	5,259	9,100	7,900	16,600	12,650	27,900	20,550	35,400	27,100
F_{2+}	41,880	50,700	46,900	77,300	63,500	137,800	98,700	214,900	143,900
F_2	306,402	310,650	308,350	312,650	310,950	289,450	301,150	272,150	296,050
F_3	276,021	260,650	267,550	226,050	244,600	179,050	212,400	113,250	166,850

Total - 944.013 Acres

Rainfall

Data Available--Adequate rainfall data were available for both August storms from recording gages at 5 stations and daily rainfall records at 31 stations distributed throughout the area. These were regularly established rainfall stations. In addition, a considerable number of supplemental rainfall catches were obtained from each storm. Also available were the U. S. Weather Bureau synoptic charts.

Meteorology--The two August storms, both of which produced very heavy rains, had dissimilar meteorological characteristics. Complete descriptions of these storms are given in the report "Floods of August 1940 in Tennessee River Basin." A brief description of each storm is given in Appendix C. In the mid-August storm, which was of large areal extent, the rainfall in the French Broad region occurred during a period of several days, but most of it fell on August 12 and 13. The late August storm, in contrast, was a short heavy rain of local nature. Practically all of the rain fell in a twenty-four hour period and the main storm occurred during the night of August 29-30.

Average Rainfall--Total rainfall was determined for each of the rainfall stations. The rainfall recorded during August 11, 12, 13, 14, and 15 was included in the mid-August total. That observed during August 29, 30, and 31 was totaled for the late August storm. Average rainfall over each area was determined giving proper weight to the rainfall at each station.

Rainfall Intensities--Rainfall patterns were determined using data from 5 recording stations in the area. They were Pink Beds, Beetree Dam, Chambers Mountain, Haywood Gap, and Coxcombe Mountain.

The recorder data for each station was abstracted from the original records, the abstractions being made in half-hourly periods. The length of period was set at 30 minutes because this is believed to be a reasonable length of time during which rainfall of shorter duration would be effective in producing infiltration.

The rainfall distribution at each intensity gage station was assumed to be characteristic of the rainfall pattern over adjacent areas. The half-hourly amounts for each area were computed by multiplying the half-hourly intensity gage amounts by the ratio of the total rainfall measured over the area to the intensity gage total.

Stream Flow

Gage Heights--Hourly gage heights were available at all gaging stations for both August floods. At Marshall, several scattered gage heights, including peak readings, were obtained from U. S. Weather Bureau records for both floods. Peak gage heights, obtained from readings at the Enka plant, were used at the Hominy Creek site. No gage heights were determined at the Cane Creek site or at the mouth of Sandymush Creek.

Peak Discharges--U. S. Geological Survey estimates of peak discharge at the regular gaging stations were generally used. Exceptions were Mills

River and Biltmore where U. S. Geological Survey ratings were revised to conform with additional information. The Marshall estimates were based on the discharge over the Redmon Dam just downstream from the town and from calculations based on high water marks and river cross sections downstream. Peak flows on Hominy Creek were obtained from high water marks and creek cross sections. The peak discharges on Cane and Sandymush Creeks were derived from rainfall and drainage basin characteristics.

Infiltration Rates

The 1940 average infiltration rates for each of the sub-watersheds were determined by two methods. The theoretical rate for summer conditions was computed for each of the areas from land use classification data. The observed rate for each of the August storms was obtained from the surface runoff and rainfall pattern. The theoretical infiltration rate, as based on land use, was used later as an index of the change in average infiltration rate corresponding to improved land use. Computation of the theoretical average infiltration rate was made using previously determined adjusted experimental infiltration rates and land use classifications.

The observed infiltration rate for each storm was determined for the various areas. The method used was to place an average infiltration rate on the rainfall pattern in a position such that the total volume of rainfall above the line equalled the total volume of surface runoff computed from the hydrograph of the area. As hydrographs were not available for three areas, Cane, Hominy, and Sandymush, the observed rates were estimated by a comparison of their theoretical rates with the theoretical rates of similar gaged areas.

Ground Water

Ground water data, including initial flow, net rise, peak, volume, and hydrograph, were developed for each area by one of two methods depending upon available information.

For areas where there were complete hydrographs, the ground water hydrograph was made by a separation. A point sufficiently far down the recession side of the hydrograph to exclude any surface runoff was selected as a starting point, and the ground water hydrograph was computed for each previous day using the ground water recession curve for that area. In this way, the ground water was backed in to the time of contraflexture of the hydrograph. A smooth curve was drawn from the initial flow, determined by inspection, to the ground water peak. The net rise was computed by subtraction of the initial flow from the ground water peak, and the ground water volume obtained by entering the ground water volume curve.

For areas where no total hydrographs were available, the procedure was followed in reverse order. Estimates of initial flow and ground water volume were based on those gaged areas with similar characteristics. With the ground water volume thus determined, the net rise was obtained from the proper ground water volume curve. Adding the net rise to the initial flow gave the peak of the ground water hydrograph which was located with respect to time as before. The ground water rise was sketched and the recession obtained from a general ground water recession curve.

Flood Hydrographs

Hydrographs were prepared for both August floods for the French Broad River at Rosman, Davidson River near Brevard, Mills River near Mills River, Mud Creek at Naples, Cane Creek at the mouth of Robinson Creek, Hominy Creek near Candler, Swannanoa River at the mouth of Bull Creek and at Biltmore, Ivy River near Marshall, Sandymush Creek at the mouth, and for the Pigeon River at Canton. Hydrographs were also developed for the reach stations on the French Broad River: Blantyre, Bent Creek, Asheville, and Marshall.

Wherever available, data for the hydrographs were obtained from the U. S. Geological Survey. These data were in the form of hourly gage heights and corresponding discharges as determined from U. S. Geological Survey ratings. Hydrographs at other than regular gaging stations were developed from rainfall, infiltration rates, and other information.

Subdivisions of Surface Runoff Hydrographs

The rainfall intensities and the hydrograph for each gaged sub-watershed were plotted to a large time scale on the same chart so that a visual correlation between parcels of rainfall and stream flow volumes could be observed. A numerical check was made between rainfall excesses for distinct parcels of rain and their respective hydrograph volumes. This was done by applying the observed average infiltration rate to the rainfall pattern and noting each distinct excess period and its excess volume which is equal to the surface runoff. In most cases, the surface runoff determined from rainfall excess agreed within reasonable limits with that determined from hydrograph separation.

Application of 20-Year Probable and Possible Land Uses

Sub-Watershed Hydrographs--To determine what effect land use improvement would have on floods in the Upper French Broad River Basin, the 20-year "probable" and "possible" land use conditions were applied to both August 1940 storms. The August 1940 rainfall patterns and amounts were used for all areas. The average infiltration rates computed for the August 1940 storms were increased by the same amounts as it was estimated that the 20-year land improvement would increase the theoretical 1940 average infiltration rates. The 20-year projected average infiltration rates were then applied to the rainfall pattern and the amounts of rainfall were computed for the same excess periods used in the 1940 analysis.

The surface runoff ordinates for each excess period were reduced by the ratio of the 20-year program excess to the 1940 excess. It was assumed that the reduction in surface runoff due to land use improvement was divided evenly between loss and ground water. Considering that for the projected programs, initial ground water flows were the same as observed in 1940, ground water hydrographs were computed. The discharges for each excess period were then added to the ground water flow to obtain the total hydrograph for the estimated 20-year "probable" and "possible" land usage.

The hydrograph reductions at Asheville and Marshall were obtained by a routing procedure through the four main river reaches, giving proper

TABLE 8

STORMS OF MID-AUGUST AND LATE AUGUST, 1940

SUMMARY OF OBSERVED DATA

SUB-WATERSHED NUMBER	SUB-WATERSHED NAME	STORM	DRAINAGE AREA Sq. Miles	AVERAGE RAINFALL Inches	INITIAL FLOW C.F.S.	INTENSITY GAGE No.	INFILTRATION RATES THEORETICAL Ins./Hour	INFILTRATION RATES OBSERVED Ins./Hour	SURFACE RUNOFF Inches	GROUND WATER RUNOFF Inches	LOSS Inches	NET GROUND WATER RISE C.F.S.	TOTAL GROUND WATER PEAK C.F.S.	TOTAL PEAK FLOW C.F.S.	PEAK GAGE HEIGHT Feet
1	Rosman	Mid-August	67.9	11.21	100	282	.38	.28	2.60	4.00	4.61	250	350	9,050	11.78
		Late August		9.24	150	282		.59	2.26	4.25	2.73	275	425	9,500	11.88
4	Davidson	Mid-August	40.4	10.99	100	282	.37	.26	2.69	1.75	6.55	150	250	6,100	9.20
		Late August		8.04	75	282		.53	1.86	2.15	4.03	200	275	4,300	7.68
5	Mills	Mid-August	66.7	11.46	75	282	.38	.25	3.10	3.62	4.74	325	400	9,200	13.15
		Late August		8.48	125	282		.44	2.70	3.80	1.98	350	475	9,850	13.62
7	Mud	Mid-August	109.0	8.78	100	282	.35	.15	3.19	1.50	4.09	200	300	8,250	12.99
		Late August		6.79	100	282		.34	2.20	1.80	2.79	250	350	4,500	10.99
8	Cane	Mid-August	60.0	5.20	50	268	.35	.21	1.20	1.07	2.93	100	150	2,030	-
		Late August		6.37	50	268		.30	1.75	1.81	2.81	150	200	3,450	-
10	Hominy	Mid-August	80.5	7.10	75	282	.35	.21	1.26	1.56	4.28	150	225	5,450	-
		Late August		7.70	75	282		.35	2.76	1.94	3.00	200	275	12,750	-
12	Bull Creek	Mid-August	95	10.35	150	268	.36	.22	3.72	3.50	3.13	500	650	16,350	-
		Late August		7.77	75	268		.29	2.68	2.40	2.69	325	400	8,900	-
12, 12A	Biltmore	Mid-August	130	9.43	200	268	.35	.21	3.29	2.75	3.39	500	700	18,400	19.00
		Late August		7.57	100	268		.34	2.18	2.30	3.09	400	500	11,200	15.34
13	Ivy	Mid-August	158	5.20	100	250	.33	.24	.83	1.23	3.14	375	475	5,850	10.32
		Late August		4.92	100	228		.26	1.27	.86	2.79	200	300	8,880	12.67
16	Sandymush	Mid-August	79.7	4.85	50	250	.29	.15	1.25	1.01	2.59	200	250	3,940	-
		Late August		7.50	50	250		.25	3.52	1.07	2.91	100	150	12,760	-
22, 23	Pigeon	Mid-August	133	11.53	500	190	.35	.18	4.40	4.45	2.68	1200	1700	25,100	18.00
		Late August		9.15	400	282		.43	3.18	4.80	1.17	1400	1800	31,500	20.75
1,2,3,4	Above Blantyre	Mid-August	296	11.36	350	282	.35	.23	3.48	-	-	-	-	-	-
		Late August		8.14	600	282		.49	2.13	-	-	-	-	-	-
5,6,7,8	Blantyre to Bent Creek	Mid-August	380	8.71	300	282	.36	.23	1.91	-	-	-	-	-	-
		Late August		7.10	400	282		.40	2.06	-	-	-	-	-	-
9,10,12,12A	Bent Creek to Asheville	Mid-August	269	8.40	150	268	.35	.29	2.18	-	-	-	-	-	-
		Late August		7.90	250	268		.38	2.10	-	-	-	-	-	-
11, 13, 16	Asheville to Marshall	Mid-August	395	4.85	250	250	.31	.16	1.17	-	-	-	-	-	-
		Late August		6.29	200	250		.28	2.17	-	-	-	-	-	-
1 - 12A	Above Asheville	Mid-August	945	9.45	800	-	-	-	2.48	1.90	4.96	1600	2400	31,800	11.65
		Late August		7.65	1250	-	-	-	2.09	2.60	2.85	2250	3500	34,800	12.15
1 - 16	Above Marshall	Mid-August	1340	8.10	1050	-	-	-	2.09	1.68	4.33	2050	3100	32,800	1638.0
		Late August		7.25	1450	-	-	-	2.11	2.11	3.03	2400	3850	61,000	1645.2

TABLE 9

STORMS OF MID-AUGUST AND LATE AUGUST, 1940

SUMMARY OF "1961 PROBABLE" PROJECTED LAND USE PROGRAM

SUB-WATERSHED NUMBER	SUB-WATERSHED NAME	STORM	INFILTRATION RATES THEORET-ICAL Ins./Hour	INFILTRATION RATES ESTIMATED Ins./Hour	SURFACE RUNOFF Inches	SURFACE RUNOFF REDUCTION Percent	GROUND WATER RUNOFF Inches	GROUND WATER RUNOFF INCREASE Percent	LOSS Inches	NET GROUND WATER RISE C.F.S.	TOTAL GROUND WATER PEAK C.F.S.	TOTAL PEAK FLOW C.F.S.	PEAK REDUCTION Percent	PEAK GAGE HEIGHT Feet	PEAK GAGE HEIGHT REDUCTION Feet
1	Rosman	Mid-August	.43	.33	2.00	23	4.30	8	4.91	275	375	7,600	16	11.28	0.50
		Late August		.64	1.98	12	4.39	3	2.87	300	450	8,250	13	11.55	0.33
4	Davidson	Mid-August	.44	.33	1.90	29	2.15	23	6.94	200	300	4,985	18	8.29	0.91
		Late August		.60	1.47	21	2.35	9	4.22	225	300	3,540	18	6.96	0.72
5	Mills	Mid-August	.44	.31	2.28	26	4.03	11	5.15	375	450	7,265	21	11.65	1.50
		Late August		.50	2.32	14	3.99	5	2.17	375	500	8,630	12	12.73	0.89
8	Cane	Mid-August	.38	.24	1.06	12	1.14	7	3.00	90	140	1,820	10	-	-
		Late August		.33	1.54	12	1.91	6	2.92	150	200	3,120	10	-	-
10	Hominy	Mid-August	.40	.26	.85	33	1.77	13	4.48	175	250	3,850	30	-	-
		Late August		.40	2.44	12	2.10	8	3.16	225	300	11,450	10	-	-
12	Bull Creek	Mid-August	.41	.27	3.28	12	3.72	6	3.35	550	700	14,580	11	-	-
		Late August		.34	2.33	13	2.58	8	2.86	350	425	7,850	12	-	-
12, 12A	Biltmore	Mid-August	.40	.26	2.90	12	2.95	7	3.58	560	760	16,250	12	18.00	1.00
		Late August		.39	1.84	16	2.47	7	3.26	430	530	9,600	14	14.40	0.94
13	Ivy	Mid-August	.39	.30	.60	28	1.34	9	3.26	460	560	4,630	21	9.21	1.11
		Late August		.32	.94	26	1.02	19	2.96	260	360	6,780	24	11.07	1.60
16	Sandymush	Mid-August	.36	.22	.79	37	1.24	23	2.82	230	280	2,650	33	-	-
		Late August		.32	2.72	23	1.47	37	3.31	130	180	10,075	21	-	-
22, 23	Pigeon	Mid-August	.40	.23	3.43	22	4.93	11	3.17	1460	1960	20,750	17	16.02	1.98
		Late August		.48	2.85	10	4.96	3	1.34	1500	1900	28,200	10	19.35	1.40
1,2,3,4	Above Blantyre	Mid-August	.41	.29	2.56	26	-	-	-	-	-	-	-	-	-
		Late August		.55	1.76	17	-	-	-	-	-	-	-	-	-
5,6,7,8	Blantyre to Bent Creek	Mid-August	.40	.27	1.45	24	-	-	-	-	-	-	-	-	-
		Late August		.44	1.82	12	-	-	-	-	-	-	-	-	-
9,10,12,12A	Bent Creek to Asheville	Mid-August	.39	.33	1.96	10	-	-	-	-	-	-	-	-	-
		Late August		.42	1.82	13	-	-	-	-	-	-	-	-	-
11,13,16	Asheville to Marshall	Mid-August	.38	.23	.75	36	-	-	-	-	-	-	-	-	-
		Late August		.35	1.58	27	-	-	-	-	-	-	-	-	-
1 - 12A	Above Asheville	Mid-August	-	-	1.94	22	2.17	14	5.34	1850	2650	27,550	13	10.66	0.99
		Late August		-	1.80	14	2.74	5	3.11	2450	3650	30,920	11	11.41	0.74
1 - 16	Above Marshall	Mid-August	-	-	1.59	24	1.91	14	4.60	2250	3300	27,680	16	1636.6	1.4
		Late August		-	1.74	18	2.27	8	3.24	2850	4300	46,000	25	1641.5	3.7

TABLE 10

STORMS OF MID-AUGUST AND LATE AUGUST, 1940

SUMMARY OF "1961 POSSIBLE" PROJECTED LAND USE PROGRAM

SUB-WATERSHED NUMBER	SUB-WATERSHED NAME	STORM	INFILTRATION RATES THEORETICAL Ins./Hour	INFILTRATION RATES ESTIMATED Ins./Hour	SURFACE RUNOFF Inches	SURFACE RUNOFF REDUCTION Percent	GROUND WATER RUNOFF Inches	GROUND WATER RUNOFF INCREASE Percent	LOSS Inches	NET GROUND WATER RISE C.F.S.	TOTAL GROUND WATER PEAK C.F.S.	TOTAL PEAK FLOW C.F.S.	PEAK REDUCTION Percent	PEAK GAGE HEIGHT Feet	PEAK GAGE HEIGHT REDUCTION Feet
1	Rosman	Mid-August	.46	.36	1.73	33	4.44	11	5.04	295	395	6,910	24	11.06	0.72
		Late August		.67	1.79	21	4.49	6	2.96	300	450	7,640	20	11.29	0.59
4	Davidson	Mid-August	.45	.34	1.80	33	2.20	26	6.99	210	310	4,820	21	8.15	1.05
		Late August		.61	1.43	23	2.37	10	4.24	230	305	3,430	20	6.85	0.83
5	Mills	Mid-August	.46	.33	2.09	33	4.12	14	5.25	400	475	6,730	27	11.19	1.96
		Late August		.52	2.20	19	4.05	7	2.23	390	515	8,250	16	12.44	1.18
8	Cane	Mid-August	.43	.29	.86	28	1.24	16	3.10	90	140	1,490	26	-	-
		Late August		.38	1.26	28	2.05	13	3.06	160	210	2,690	22	-	-
10	Hominy	Mid-August	.43	.29	.66	48	1.86	19	4.58	185	260	3,170	42	-	-
		Late August		.43	2.26	18	2.19	13	3.25	230	305	10,650	16	-	-
12	Bull Creek	Mid-August	.43	.29	3.13	16	3.80	9	3.42	560	710	13,930	15	-	-
		Late August		.36	2.18	19	2.65	10	2.94	350	425	7,430	17	-	-
12, 12A	Biltmore	Mid-August	.42	.28	2.75	16	3.02	10	3.66	570	770	15,420	16	17.58	1.42
		Late August		.41	1.70	22	2.54	10	3.33	450	550	8,990	20	14.04	1.30
13	Ivy	Mid-August	.42	.33	.53	36	1.38	12	3.29	490	590	4,180	29	8.80	1.52
		Late August		.35	.82	35	1.08	26	3.02	290	390	6,020	32	10.43	2.24
16	Sandymush	Mid-August	.40	.26	.63	50	1.32	31	2.90	250	300	2,300	42	-	-
		Late August		.36	2.32	34	1.67	56	3.51	145	195	8,680	32	-	-
22, 23	Pigeon	Mid-August	.42	.25	3.11	29	5.10	15	3.32	1600	2100	19,190	24	15.28	2.72
		Late August		.50	2.73	14	5.02	5	1.40	1550	1950	26,980	14	18.82	1.93
1,2,3,4	Above Blantyre	Mid-August	.44	.32	2.22	36	-	-	-	-	-	-	-	-	-
		Late August		.58	1.61	24	-	-	-	-	-	-	-	-	-
5,6,7,8	Blantyre to Bent Creek	Mid-August	.44	.31	1.12	41	-	-	-	-	-	-	-	-	-
		Late August		.48	1.58	23	-	-	-	-	-	-	-	-	-
9,10,12,12A	Bent Creek to Asheville	Mid-August	.42	.36	1.83	16	-	-	-	-	-	-	-	-	-
		Late August		.45	1.64	22	-	-	-	-	-	-	-	-	-
11, 13, 16	Asheville to Marshall	Mid-August	.41	.26	.62	47	-	-	-	-	-	-	-	-	-
		Late August		.38	1.38	36	-	-	-	-	-	-	-	-	-
1 - 12A	Above Asheville	Mid-August	-	-	1.67	33	2.30	21	5.48	1950	2750	25,200	21	10.10	1.55
		Late August		-	1.61	23	2.84	9	3.20	2550	3800	28,050	19	10.78	1.37
1 - 16	Above Marshall	Mid-August	-	-	1.36	35	2.02	20	4.72	2400	3450	25,400	23	1635.8	2.2
		Late August		-	1.54	27	2.38	13	3.33	3000	4450	40,250	34	1640.0	5.2

TABLE 11

STORM OF JULY, 1916

SUMMARY OF OBSERVED DATA

SUB-WATERSHED NUMBER	NAME	DRAINAGE AREA Sq. Miles	AVERAGE RAINFALL Inches	INITIAL GROUND WATER C.F.S.	INFILTRATION RATES THEORETICAL Ins./Hour	ESTIMATED* Ins./Hour	SURFACE RUNOFF Inches	GROUND WATER RUNOFF Inches	LOSS Inches	NET GROUND WATER RISE C.F.S.	TOTAL GROUND WATER PEAK C.F.S.	TOTAL PEAK FLOW C.F.S.	PEAK GAGE HEIGHT Feet
1	Rosman	67.9	8.71	360	.38	.28	3.73	2.31	2.67	130	490	18,200	13.87
4	Davidson	40.4	8.71	350	.37	.26	3.98	1.00	3.73	70	420	7,400	10.07
5	Mills	66.7	6.97	260	.38	.25	2.36	2.00	2.61	130	390	8,400	12.58
7	Mud	109.0	15.93	350	.35	.15	12.61	.89	2.43	120	470	40,460	21.52
8	Cane	60.0	16.53	180	.35	.21	12.42	1.10	3.01	80	260	24,030	11.4
10	Hominy	80.5	4.30	260	.35	.21	.56	1.00	2.74	100	360	2,360	-
12	Bull Creek	95	8.42	520	.36	.22	4.19	2.23	2.00	280	800	21,950	-
12, 12A	Biltmore	130	7.68	700	.35	.21	3.57	1.84	2.27	310	1010	23,000	20.72
13	Ivy	158	6.37	350	.33	.24	1.89	1.26	3.22	380	730	10,200	13.59
16	Sandymush	79.7	2.30	180	.29	.15	.25	.58	1.47	60	240	1,030	-
1,2,3,4	Above Blantyre	296	12.65	1220	.35	.23	8.30	-	-	-	-	-	-
5,6,7,8	Blantyre to Bent Creek	380	12.60	1050	.36	.21	8.54	-	-	-	-	-	-
9,10,12,12A	Bent Creek to Asheville	269	6.12	530	.35	.21	2.13	-	-	-	-	-	-
11,13,16	Asheville to Marshall	395	4.85	880	.31	.16	1.39	-	-	-	-	-	-
1 - 12A	Above Asheville	945	10.77	2800	-	-	6.64	1.15	2.98	1000	3800	103,000	23.1
1 - 16	Above Marshall	1340	9.01	3970	-	-	5.09	1.13	2.79	1530	5500	97,600	1648.5

* Estimated Infiltration Rate is the Observed Rate for Mid-August 1940 flood.

consideration to reductions in local inflows and changes in ground water flows.

Reduction in Flood Peaks

The results of the determinations of the effect of the projected land use programs on stream flow are shown on hydrographs prepared for each sub-watershed. Typical of these hydrographs are those shown on plate 42. This shows the reductions which have been computed on the French Broad River at Asheville for the mid-August flood and on the Ivy River near Marshall for the late August flood for the two land use programs.

Table 8 is a summary of observed data for the two August 1940 floods. Tables 9 and 10 are summaries of the results of the application of the "probable" and "possible" projected land use programs for each of the respective areas. The last column in tables 9 and 10 shows the estimated reduction in peak gage height in feet for each sub-watershed. The peak discharges and gage heights shown on these tables in a few cases differ slightly from the discharges and gage heights finally determined. These minor differences have only a negligible effect on the peak gage height reductions.

Flood of July 1916

The mid-July 1916 flood is the largest general flood of record in the Upper French Broad basin. Most of the rain causing this flood fell on July 15 and 16, 1916. Although there is only a limited amount of basic data for this flood, it was studied to determine the effect of land use on a flood of such magnitude. The area studied is the same as that for the 1940 floods, except that the Pigeon basin, which had no flood, was not included.

The relative size of the July 1916 flood with respect to floods of record and to the largest flood of August 1940 is shown by the following tabulation.

Location	Order of Magnitude of 1916 Flood	Largest 1940 Flood Peak in Percent 1916 Flood Peak
French Broad River at Rosman	1	52
French Broad River at Blantyre	1	35
French Broad River at Bent Creek	1	22
French Broad River at Asheville	1	34
French Broad River at Marshall	1	62
Mud Creek at Naples	1	20
Cane Creek at mouth of Robinson Creek	1	14
Swannanoa River at Bull Creek	2	74
Swannanoa River at Biltmore	2	80
Davidson River near Brevard	4	82
Ivy River near Marshall	2	87
Mills River near Mills River	4	117
Sandymush Creek at mouth	Small	1240
Hominy Creek near Candler	Small	540

Rainfall

Development of Storm Rainfall--Rainfall for this great storm was recorded at too few stations to provide adequate data for a satisfactory study of this storm. In order to have a basis for investigating the effect of land use improvements on runoff from this storm, an isohyetal map of probable rainfall was developed. The methods by which this was done are described in Appendix C. Plate 46 is the isohyetal map.

Although the July 1916 storm produced a much larger flood than those of August 1940, the average rainfall over the basin was not appreciably higher. However, effective rainfall was much higher because of the uneven distribution of the rainfall over the area. In addition to different areal distribution, concentration of rainfall into a major excess period and high initial flow were factors contributing to the magnitude of the July 1916 flood.

Prior Conditions--A storm over this region from the 8th to the 10th of July caused heavy rainfall and resulted in general floods on the Upper French Broad River area. Although the surface runoff had receded before the July 15-16 rainfall, which caused the major flood, the ground was still effected by the July 8-10 rainfall and by light rains which fell from July 10 to 15.

Stream Flow

Gage height hydrographs have been developed for the French Broad River at Rosman and Asheville from the best available data. In addition, crest gage heights were determined from high water marks and flood profiles for the French Broad River at Blantyre, Bent Creek, and Marshall, and for the following tributaries: Swannanoa at Biltmore, Mills River near Mills River, Davidson River near Brevard, Mud Creek at Naples, Cane Creek at the mouth of Robinson Creek, and Ivy River near Marshall.

Ground Water

It was assumed that the same ratio existed between ground water volume and loss in the July 1916 flood as in the flood of mid-August 1940. Ground Water hydrographs were determined from total discharge hydrographs developed at Rosman and Asheville. It was found that the initial ground water flows were respectively 3.6 and 3.5 times the mid-August 1940 initial ground water flows. In the absence of ground water data for other areas, initial ground water flow was assumed to be 3.5 times the mid-August 1940 initial flow.

Infiltration Rates

No studies were made to estimate 1916 land use. It was assumed that land use was similar in 1916 to that in 1940, and that the infiltration rates determined for 1940 land use are applicable to 1916. The observed infiltration rates determined in the analysis of the mid-August 1940 flood were used throughout the July 1916 flood analysis. These low mid-August 1940 infiltration rates were selected in preference to the theoretical or late August 1940 rates because the mid-August storm, like the 1916 storm,

TABLE 12

STORM OF JULY, 1916

SUMMARY OF "20 YEAR PROBABLE" PROJECTED LAND USE PROGRAM

SUB-WATERSHED NUMBER	SUB-WATERSHED NAME	INFILTRATION RATES THEORETICAL Ins./Hour	INFILTRATION RATES ESTIMATED Ins./Hour	SURFACE RUNOFF Inches	SURFACE RUNOFF REDUCTION Percent	GROUND WATER RUNOFF Inches	GROUND WATER RUNOFF INCREASE Percent	LOSS Inches	NET GROUND WATER RISE C.F.S.	TOTAL GROUND WATER PEAK C.F.S.	TOTAL PEAK FLOW C.F.S.	PEAK REDUCTION Percent	PEAK GAGE HEIGHT Feet	PEAK GAGE HEIGHT REDUCTION Feet
1	Rosman	.43	.33	3.10	17	2.63	14	2.98	150	510	15,260	16	13.25	0.62
4	Davidson	.44	.33	3.10	22	1.44	44	4.17	110	460	5,890	20	9.05	1.02
5	Mills	.44	.31	1.62	31	2.37	18	2.98	170	430	5,830	31	10.35	2.23
7	Mud	.39	.19	12.08	4	1.15	29	2.70	150	500	38,940	4	21.20	0.32
8	Cane	.38	.24	12.05	3	1.28	16	3.20	100	280	23,360	3	11.25	0.15
10	Hominy	.40	.26	.38	32	1.09	9	2.83	100	360	1,550	34	-	-
12	Bull Creek	.41	.27	3.57	15	2.54	14	2.31	330	850	18,790	14	-	-
12, 12A	Biltmore	.40	.26	2.95	17	2.15	17	2.58	360	1060	19,140	17	19.35	1.37
13	Ivy	.39	.30	1.15	39	1.63	29	3.59	560	910	6,400	37	10.73	2.86
16	Sandymush	.36	.22	.14	44	.64	10	1.52	60	240	830	19	-	-
1,2,3,4	Above Blantyre	.41	.29	7.54	9	-	-	-	-	-	-	-	-	-
5,6,7,8	Blantyre to Bent Creek	.40	.25	7.99	6	-	-	-	-	-	-	-	-	-
9,10,12,12A	Bent Creek to Asheville	.39	.25	1.71	20	-	-	-	-	-	-	-	-	-
11,13,16	Asheville to Marshall	.38	.23	.71	49	-	-	-	-	-	-	-	-	-
1 - 12A	Above Asheville	-	-	6.05	9	1.45	26	3.27	1200	4000	94,000	9	22.1	1.0
1 - 16	Above Marshall	-	-	4.48	12	1.44	27	3.09	1930	5900	89,500	8	1648.1	0.4

TABLE 13

STORM OF JULY, 1916

SUMMARY OF "20 YEAR POSSIBLE" PROJECTED LAND USE PROGRAM

SUB-WATERSHED NUMBER	SUB-WATERSHED NAME	INFILTRATION RATES THEORET-ICAL Ins./Hour	INFILTRATION RATES ESTIMATED Ins./Hour	SURFACE RUNOFF Inches	SURFACE RUNOFF REDUCTION Percent	GROUND WATER RUNOFF Inches	GROUND WATER RUNOFF INCREASE Percent	LOSS Inches	NET GROUND WATER RISE C.F.S.	TOTAL GROUND WATER PEAK C.F.S.	TOTAL PEAK FLOW C.F.S.	PEAK REDUCTION Percent	PEAK GAGE HEIGHT Feet	PEAK GAGE HEIGHT REDUCTION Feet
1	Rosman	.46	.36	2.73	27	2.81	22	3.17	160	520	13,500	26	12.85	1.02
4	Davidson	.45	.34	2.98	25	1.50	50	4.23	120	470	5,670	23	8.85	1.22
5	Mills	.46	.33	1.36	42	2.50	25	3.11	180	440	4,970	41	9.40	3.18
7	Mud	.43	.23	11.58	8	1.41	58	2.94	190	540	37,480	7	20.90	0.62
8	Cane	.43	.29	11.42	8	1.60	45	3.51	120	300	22,200	8	11.0	0.40
10	Hominy	.43	.29	.28	50	1.14	14	2.88	100	360	1,150	51	-	-
12	Bull Creek	.43	.29	3.31	21	2.67	20	2.44	350	870	17,550	20	-	-
12, 12A	Biltmore	.42	.28	2.70	24	2.28	24	2.70	400	1100	17,620	23	18.65	2.07
13	Ivy	.42	.33	.86	54	1.78	41	3.73	640	990	4,970	51	9.51	4.08
16	Sandymush	.40	.26	.09	64	.66	14	1.55	60	240	720	30	-	-
1,2,3,4	Above Blantyre	.44	.32	7.17	14	-	-	-	-	-	-	-	-	-
5,6,7,8	Blantyre to Bent Creek	.44	.29	7.49	12	-	-	-	-	-	-	-	-	-
9,10,12,12A	Bent Creek to Asheville	.42	.28	1.50	30	-	-	-	-	-	-	-	-	-
11,13,16	Asheville to Marshall	.41	.26	.52	63	-	-	-	-	-	-	-	-	-
1 - 12A	Above Asheville	-	-	5.68	14	1.63	42	3.46	1400	4200	88,000	15	21.5	1.6
1 - 16	Above Marshall	-	-	4.16	18	1.60	42	3.25	2120	6090	84,000	14	1647.8	0.7

was preceded by rainfall which reduced infiltration to a relatively small amount.

July 1916 Hydrographs

Hydrographs were developed by the methods most applicable depending on the available data for each of the sub-watersheds and for the four main river reaches. This procedure is the same as for the 1940 floods except that the basic data was more scant for the 1916 flood.

Application of 20-Year Probable and Possible Land Uses

Each sub-watershed was analyzed to determine the amount of reduction in the July 1916 flood when the 20-year future "probable" and "possible" land use improvement programs were applied. Future infiltration rates computed for the mid-August 1940 flood were used in this study, and the procedure followed was the same as that used in the 1940 analysis. The future Asheville and Marshall hydrographs were developed by using the same methods used for the 1940 floods.

Reduction in Flood Peaks

Tables 11, 12, and 13 summarize the available data for the July 1916 flood and the effects of the projected land use programs.

At Asheville the estimated reductions in peak discharge for the 1916 flood, applied to the 20-year future "probable" and "possible" land use programs, were respectively 9 and 15 percent. These compare with peak discharge reductions of about 12 and 20 percent for the August 1940 floods. The peak gage height reduction at Asheville would be 1.0 and 1.6 feet for the 1916 flood. The peak gage height reductions at Asheville were consistent for all three storms.

The analysis of the July 1916 storm for the Hominy Creek drainage area shows that future "probable" and "possible" land use improvement may reduce peak discharges for summer storms of about four inches by 34 and 51 percent. For higher summer rainfalls of about 9 inches, as occurred in July 1916 on the Davidson River, reductions of peak may be about 20 and 23 percent. The Cane Creek watershed for the July 1916 storm shows that for extremely high rainfalls, the reductions corresponding to the two land use programs are only about 3 and 8 percent respectively. These figures show that the largest benefits from improved land use are to be expected during moderate storms and that in the great storms of infrequent occurrence, the effect of land use on flood peaks is the least.

Tennessee Valley Authority
Water Control Planning Department

APPENDIX G

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Knoxville, Tennessee
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